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AUG 77 J M MILLER, A P ANDREWS, T F BRASHER F33615-75-C-1301
UNCLASSIFIED C75-787/201-VOL-2 AFAL-TR-77-138-VOL-2 NL

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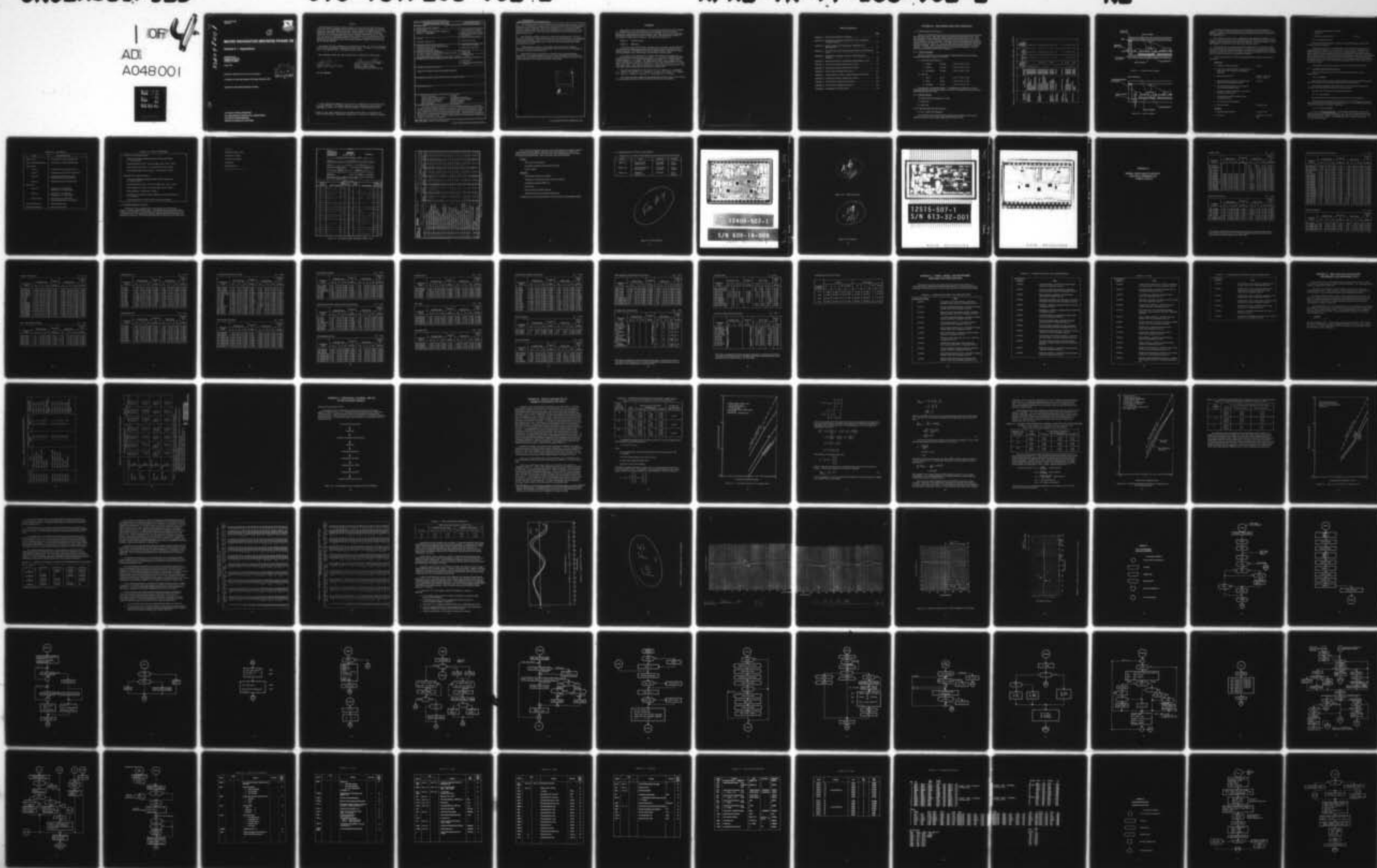

AFAL-TR-77-138
Volume II

ADA048001

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MICRO NAVIGATOR (MICRON) PHASE 2B

Volume II — Appendices

Autonetics Group
Rockwell International
3370 Miraloma Avenue
Anaheim, CA 92803

August 1977

TECHNICAL REPORT AFAL-TR-77-138, VOLUME II

Final Report for the Period 5 August 1975 through 25 February 1977

Approved for public release; distribution unlimited.

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RONALD E. JANOSKO, Capt, USAF
MICRON Project Manager, ADP-666A

RONALD L. RINGO, Chief
Reference Systems Branch
Reconnaissance & Wpn Delivery Div

FOR THE COMMANDER

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Cost of Ownership
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Micro Electrostatic Gyro
Micro Navigator
MICRON
Navigation Performance
Strapdown Inertial Navigator
Standard Navigator
Sure Start Gyro

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Micro Navigator (MICRON) is a low-cost highly reliable, and moderately accurate strapdown inertial navigator. The heart of the MICRON system is the micro-electrostatic gyro (MESG), an instrument which incorporates an all-attitude, whole-angle readout from an electrostatically suspended rotor. Under previous Air Force contracts two developmental navigation systems (N57A-1 and N57A-2) were designed, fabricated, and flight tested. Two gyro subassemblies for developmental testing were designed, fabricated, and integrated.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

The overall objective of the MICRON Phase 2B contract was to design, develop, fabricate, and integrate the Engineering Prototype MICRON (EPM) and its associated software and test equipment. The specific objectives were to develop a MICRON system resulting in high reliability, ease of maintenance, low acquisition cost, and moderate performance, and be a potential candidate as the inertial navigation unit (INU) for the F-16.

One EPM was designed, fabricated, assembled, and integrated. The EPM meets the performance requirements of the Phase 2B contract and the F-16 packaging envelope requirements. Spares were fabricated and tested to support maintenance of the EPM. Test Equipment, system software, and test station software were developed and verified.

System analyses, studies, and tradeoffs were made which resulted in improved accuracy, reliability, producibility, and life cycle costs. Design specifications were prepared and maintained.

Integration testing was conducted to establish system compatibility and operability. Seventeen navigation performance runs, including two demonstration runs, were made during integration testing. Position and velocity errors were well within (approximately one-half) the contract requirement.

FOREWORD

This report was prepared under Air Force Contract F33615-75-C-1301, Project No. ADP 666A and covers work performed by the Autonetics Group of Rockwell International, 3370 Miraloma Avenue, Anaheim, CA 92803, for the Air Force Avionics Laboratory, Wright-Patterson Air Force Base, Ohio. This final report consists of two volumes of which this is Volume II. The titles of the volumes are:

Volume I   Technical Report

Volume II   Appendices

The purpose of the MICRON Phase 2B contract was to design, develop, fabricate, and integrate the Engineering Prototype MICRON (EPM) and its associated software and test equipment. The MICRON is a low cost, highly reliable, moderately accurate inertial navigation system which utilizes electrostatic gyroscopes (ESG).

This program was conducted from 5 August 1975 through 25 February 1977. It was directed by the MICRON Program Manager, J. A. Schwarz; the MICRON Assistant Program Manager, J. E. Menzel; the Engineering Manager, A. P. Truban; and the Project Engineer, G. E. Runyon. The cognizant Air Force Project Managers on this phase of the MICRON program were Captain W. G. Peterson and Captain R. E. Janosko, AFAL/RWA-666A. The contractor submitted the draft of this report in May 1977. The contractor's final submittal date of this report was August 1977.

The principal contributors to this report were A. P. Andrews, T. F. Brasher, H. L. Bump, J. D. Courtier, K. J. Gibson, F. J. Gulde, F. R. Hall, D. W. Holmes, K. K. Jin, L. E. Johnsen, J. Jurison, J. F. Klinchuch, and J. M. Miller.

This report has been assigned the Internal Rockwell Control Number, C75-787/201. All correspondence relating to this document should reference this number.

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APPENDIX A. EPM HYBRID STATUS AND TECHNOLOGY

A.1 HYBRID DESIGN AND STATUS

There are 31 different hybrid circuit types and a total of 63 hybrids utilized within the EPM (N73) system. Both thick and thin film substrate technology is used. Thin film technology is used when good resistor stability and tracking is required. Thick film technology is used in logic-type hybrids and hybrids where resistor performance requirements are not too demanding. A summary of the hybrids fabricated, assembled, and tested is given in Table A-1. Halex Inc. fabricated the substrates which utilize the thin film technology. Halex resistor networks have been shown to provide very good stability. The thick film hybrid substrates were fabricated at Autonetics. All the hybrids were assembled and tested at Autonetics.

A.1.1 Hybrid Packaging

Two basic schemes are used to package the MICRON Phase 2B Hybrid Microelectronics as shown in Figure A-1 and A-2.

I. FLATPACK (BUTTERFLY)

1.	IP1605-1	60 leads	1.700 x 0.945 x 0.125
2.	IP1605-4	30 leads	1.700 x 0.945 x 0.125
3.	IP1100MOD	40 leads	1.130 x 0.945 x 0.263

II. PLUG IN

1.	35018	31 pin	1.770 x 1.245 x 0.191
2.	35019	63 pin	1.770 x 1.245 x 0.191
3.	35019Q01	47 pin	1.770 x 1.245 x 0.191

The packages are gold plated Kovar. The flatpacks are soldered to the PCB board material, and the Plug in packages are inserted into sockets with the four corner pins soldered down to the PCB.

A.1.2 Hybrid Circuits

Two types of hybrid technology are used:

I. Thick Film

II. Thin Film

A.1.3 Substrate Materials and Processes

A.1.3.1 Thick Film Multilayer

The substrate material for hybrids using thick film multilayer is 96 percent unglazed alumina having a surface finish of 25 microinches CLA.

TABLE A-1. SUMMARY OF EPM HYBRIDS FABRICATED, ASSEMBLED, AND TESTED

MLB on which Hybrid is Mounted	Hybrid Circuit Nomenclature	Hybrid Circuit Part Number	Substrate Technology		Qty Req'd Per System	Qty of Spares Req'd for EPM	Qty of Hybrids Fabricated, Assembled, and Tested
			Thin Film	Thick Film			
Suspension and	Servo Network	12405–507		X	2	2	4
MUM Electronics	Differential Angle/Notch Filter	12410–507	X		2	2	4
Module (SEU 1 & 2)	MUM Demodulator	12415–507	X		2	2	4
	MUM Demodulator Filter	12420–507	X		2	2	4
	Modulator	12425–507	X		4	3	7
	Multiplexer	12430–507	X		2	2	4
	MUM Demod Sample & Hold	12435–507	X		2	2	4
	Sample & Hold/Gap Summation	12520–507	X		4	3	7
Timing and	*A/D Converter*	12440–507	X		1	2	3
Sequencing Electronics	Suspension Timing Generator	12445–507		X	1	2	3
Module (SEU 3)	Sequencer No. 1	12450–507		X	1	2	3
	Sequencer No. 2	12455–507		X	1	2	3
	Precision Crystal Osc./Gap Monitor	12470–507		X	1	2	3
	50 kHz Buffer/EMA Pwr Supply	*12475–507*		X	1	2	3
	DC Ref & Preload Modulator	12480–507	X		1	2	3
	EMA Signal Filter	12495–507		X	1	2	3
	Ladder Network	12565–507	X		1	2	3
Signal Generator	Spin Motor Controller	12485–507		X	1	2	3
and Memory	Temperature Controller	12490–507		X	1	2	3
Electronics Module	Cal Constant Storage No. 1	12460–507		X	1	1	2
(SEU 4)	Cal Constant Storage No. 2	12465–507		X	1	1	2
Charge Amplifier Electronics Module	Charge Amplifier	12400–507	X		16	10	26
Spin Motor Electronics Assembly	Spin Motor Power Preamp.	12525–507		X	1	2	3
Converter Electronics	Synchro Bite	12505–507		X	1	2	3
Module	Synchro Buffer Amplifier	12510–507	X	X	3	4	7
	Synchro Reference Generator	12515–507		X	1	2	3
	Synchro DAC	12545–507	X		2	3	5
	DAC Amplifier	12560–507	X		1	2	3
Data Terminal Unit	Transmitter/Receiver	12503–507	X	X	2	3	5
	Encoder	12535–507		X	1	2	3
	Decoder	12540–507		X	2	3	5

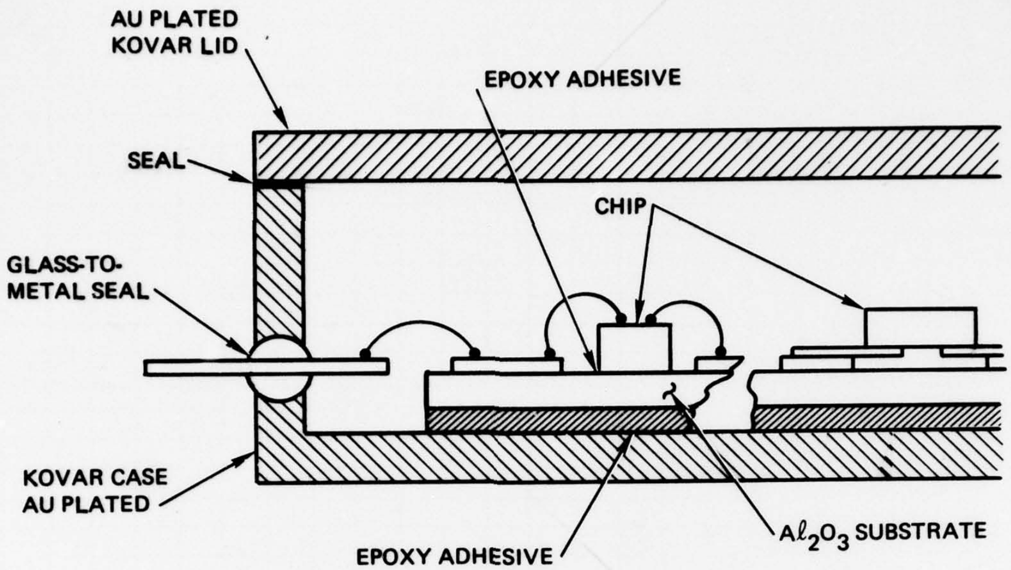

Figure A-1. Flatpack Metal Package

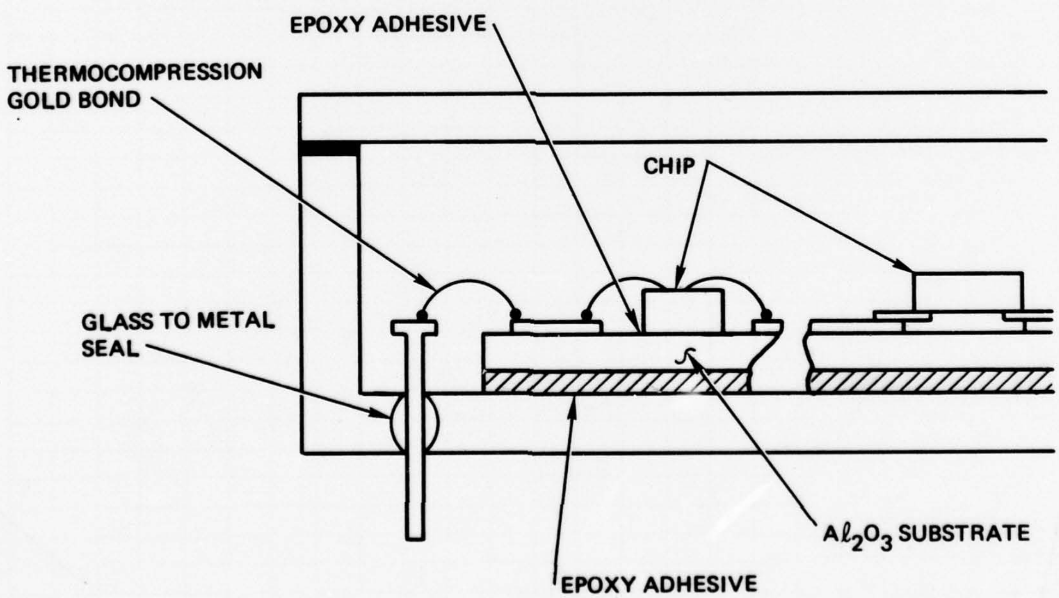

Figure A-2. Plug In Package

The alumina substrate is used as the insulating base on which a number of conductor, resistor, and insulating layers are sequentially screened and fired. The insulated conductor layers are connected using a system of filled vias (or windows) in the insulating layer.

The conductor material used is a high gold content fritless gold (0I6990). Gold conductor compositions are used in all applications requiring thermocompression wire bonding, beam lead bonding and ultrasonic wire bonding. The sheet resistivity of fired gold conductor compositions is less than 0.005 ohms per square.

The insulator is a low K composition glass-ceramic ($K = 6$ to 12) and is used to provide insulation between conductor layers. Typical crossover capacitance between two 0.005 in. wide line running perpendicular to each other and separated by a nominal insulator thickness of 0.001 in. is 0.05 pF. Two layers of insulation between conductor layers are used to minimize any possibility of pinholes.

The following criteria are used to design high density multilayer interconnect structures:

<u>Conductors</u>

1.	Minimum width and spacing	0.005 in.
2.	Lines are oriented parallel or perpendicular to each other and the edges of rectangular substrate	
3.	Beam lead bond sites	0.006 in. wide with 0.004 in. space
4.	Spacing between upper layer conductor and edge of device installation window	0.005 in.
5.	All beam lead bond sites are screened on the lowest metalization level	
6.	Maximize conductor densities on the lowest possible conductor layer	
7.	Avoid adjacent parallel conductor runs on different layers	
8.	Use two levels of conductors	
9.	Wire bond sites	0.005 sq. min.

<u>Insulator</u>

1.	Substrate edge distance	0.005 in. min.
2.	Via size	0.0075 in. x 0.010 in. min.

3. Vias connecting parallel conductors staggered.

4. Minimum insulator width 0.005 in.

A.1.3.2 Plated Thin Film

The plated thin film substrate is used in metal hybrid packages where stable resistor values are required.

The thin film substrate is an unglazed 99.5 percent alumina structure with a surface finish in the order of 2 to 6 microinches CLA (as fired). The substrate is coated with gold over nickel over nichrome in a vacuum deposition chamber. The deposited gold is electrodeposited with gold to provide gold TC beam lead bondability and low sheet resistivity. The nichrome provides metalization adhesion to the substrate and a nickel barrier is deposited between the gold and nichrome to eliminate adverse conditions caused by stresses at the interface. The conductor pattern is delineated by a chemical etch process. The resistors are stabilized in air at 230°C for 95 hr then at 150°C for 168 hr.

The conductor interconnect design criteria is basically that of thick film.

A.1.4 Assembly Materials and Processes

Table A-2 summarizes the use of materials in fabricating the hybrid microcircuits.

A.1.4.1 Organics

Nonconductive epoxy is used to attach; substrate-to-case; non-beam lead active and passive elements (not requiring back contact) and transformers.

Electrically conducting, silver filled epoxy is used to attach nonbeam lead active devices (requiring back contact) and chip capacitors.

See Table A-3 for specific epoxy material properties.

A.1.4.2 Microjoining

Beam lead devices are bonded using one-at-a-time TC bonding (IC's).

Ultrasonically bonded aluminum or gold wires (1.00 mil diameter) are used to interconnect nonbeam lead active and passive devices. 1.5 mil diameter gold wires will be used for case-to-substrate connections.

A.1.4.3 Hermetic Sealing

A.1.4.3.1 Metal Package Seal. An 80-20 gold-tin preform is used as the sealant between the gold plated package and lid. The seal is effected using a Solid State Equipment Corp. (SSEC) seam sealer which allows the substrate to case epoxy bond line to be held at < 100°C. Acceptable leak rate is equal to or less than 5×10^{-7} He ATM cc/sec.

TABLE A-2. MATERIALS

Bond	Method/Materials
Sub-To-Case	Nonconductive Epoxy (Ablefilm 529)
Sub-To-Sub (Charge Amp)	Nonconductive Epoxy (Ablefilm 529)
Chip-To-Sub	
- Chip C's	Conductive Epoxy (Able Bond 36-2)
- Chip R's	Nonconductive Epoxy (ECCO Bond 104)
- Chip IC's	Conductive/nonconductive Epoxy (Able Bond 36-2/ECCO Bond 104)
- Chip Q's	Conductive Epoxy (Able Bond 36-2)
Wire Bond	
- Chip IC's	Ultrasonic A on Thin Film Ultrasonic AU on Thick Film
- Chip Q's	Ultrasonic A on Thin Film Ultrasonic AU on Thick Film
- Pack-To-Sub	Ultrasonic AU on Flat Packs Thermocompression AU on Plug In
Beam Lead Devices	Thermocompression
Seal (Metal Package)	Seam Seal (Gold-Tin)

TABLE A-3. EPOXY PROPERTIES

Eccobond 104 (Insulative Epoxy)
Meets NASA Outgassing Requirements for Space Application (< 1 percent TWL)
Thermal Stability (TGA): Flat (No Weight Loss), 100°C - 300°C
Total Weight Loss (TWL): 0.1 percent After 700 hr at 150°C
Shear Strength (With 150-6 Primer): >880 PSI (20°C - 250°C)
Ablebond 36-2 (Conductive Epoxy)
Meets NASA Outgassing Requirements for Space Application (< 1 percent TWL)
Thermal Stability (TGA): FLAT (No Weight Loss), 100°C - 300°C
Total Weight Loss (TWL): 0.4 percent after 700 hr at 150°C
Shear Strength: >880 PSI (20°C - 250°C)
No Evidence of Corrosion or Silver Migration at 85 percent RH, and 85 C for 200 hr
Volume Resistivity: 0.0001 ohms-cm (Vendor Data Sheet)

A.2 HYBRID ASSEMBLY AND TEST

All hybrid circuits are fabricated per Documented ESWA procedures. Figure A-3 shows a typical ESWA Ticket. This ticket shows the step-by-step flow of operations performed on the hybrids and the process specifications utilized in the assembly process. The operator or inspector signs and dates the ticket when each operation is completed. All rework information is also recorded on the ESWA ticket.

Post Seal

Stabilization bake (24 hr)

Temperature cycling

Constant acceleration

Hermeticity

Burn-In (168 hr)

Final functional test Hi ambient

PAGE NO. 1

A246290

IF NOT ORIG. ESWA NO. ENTER ORIG. NO. BELOW

ESWA

MICRON PHASE 2B

SHOP JOB NO. ______

TO D/244, 251, 252 & 253 FROM D/252 DATE ______

ACCEPTED BY ______ AUTHORIZED BY ______

CHARGE NO. ______ EST. HOURS ______ EST. COMPLETION DATE ______

DOCUMENTATION REQ'D YES [X] NO [ ] TO BE FLIGHT TESTED OR DELIV'D YES [X] NO [ ]

MAT'L TO BE FURN. BY RESP. ENG. [ ] 881-C No. ______ ENG. SHOP [ ] 881-C No. ______

INSTRUCTIONS RESP. ENG. L. R. Enlow EXT. 1452

Perform microcircuit assembly, test and inspection per the applicable microcircuit drawing and page 2 of this ESWA.

REWORK RECORD

DATE	FAILED ITEM/ TEST NO.	REWORK REQUIRED	REWORK OK OPER	REWORK OK DATE	DATE	FAILED ITEM/ TEST NO.	REWORK REQUIRED	REWORK OK OPER	REWORK OK DATE

Figure A-3. Documented ESWA Procedures (Sheet 1 of 2)

PAGE NO. 2

A246290

ESWA MICRON PHASE 2B CIRCUIT NAME ____

P/N ____

S/N ____

	Dept.	Task	OPER/INSP	DATE	REWORK OPER/INSP	DATE	OPER/INSP	DATE	OPER/INSP	DATE	OPER/INSP	DATE	OPER/INSP	DATE
1	252	Fab & identify substrate												
2	176	Verify substrate acceptance												
3	252	Clean substrate/AA0110-033, Method I												
4	252	Mount beam lead devices/AA0107-077												
5	252	Mark case/applicable circuit drawing												
6	252	Clean case/AA0110-033, Method I												
7	252	Assemble circuit/AL70089												
8	252	Bond/circuit drawing												
9	252	Bond pull flying leads/AA0115-142												
10	252	Clean circuit/AA0110-033, Method II												
11	252	Eng'g visual inspection												
12	244	F/T (AMB/HI)/applicable F/T spec												
13	252	Clean ckt/AA0110-033, Method II												
14	253	Preseal INSP/AA0115-141, Class B												
15	251	Clean cover/AA0110-033, Method V												
16	251	Seal ckt/AA0107-081, Method I												
17	251	Gross leak test/AA0115-079												
18	251	Mark cover/applicable circuit drawing												
19	251	Stabilization bake/AA0115-145, Class B												
20	251	Temp Cycle/AA0115-145, Class B												
21	251	Centrifuge/AA0115-145, Class B												
22	251	Hermeticity test/AA0115-145, Class B except 15 psi for 6 hour minimum.												
23	253	Burn-in/TEM												
24	244	F/T (AMB/HI)/applicable F/T spec												
25	253	INSP & Closeout/AA0115-145, Class B												

Figure A-3. Documented ESWA Procedures (Sheet 2 of 2)

The process specifications called out on the ESWA ticket are compatible with the requirements of MIL-M-38510. The screen tests are essentially the same as the Class B screen tests specified in MIL-STD-883. One-hundred percent screen tests are performed on all hybrids. The screen tests include the following:

<u>Preseal</u>

100 percent wire bond pull

Operating temperature functional test (Final)

Internal visual

<u>Post-Seal</u>

Stabilization bake (24 hr at 125°C)

Temperature cycling (10 cycles (-55°C and +125°C)

Constant acceleration (3000 G's)

Hermeticity

Burn-in (168 hr at 105°C ambient)

Final functional test (operating temperature)

All data have been recorded each time a hybrid circuit was functionally tested.

A. 3 DESCRIPTION OF TYPICAL EPM HYBRIDS

Figures A-4, A-5 and A-6 show samples of the hybrid types used in the EPM.

Figure	Item	Substrate	Package
Figure A-4	Servo Network (12405-507-1)	Two-layer thick film	31 pin plug-in
Figure A-5	MUM Demodulator (12515-507-1)	Two-layer thick film	60 pin flatpack
Figure A-6	Modulator (12425-507-1)	Thin-film	47 pin plug-in

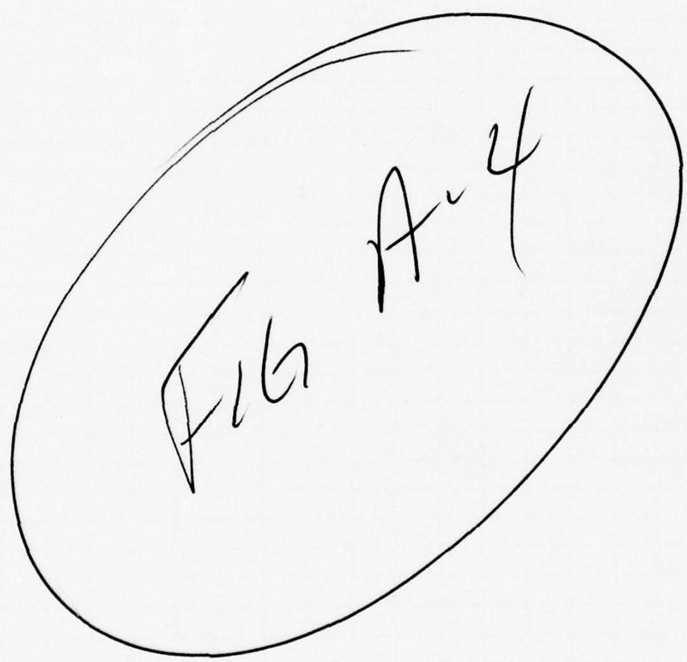

Figure A-4. Servo Network

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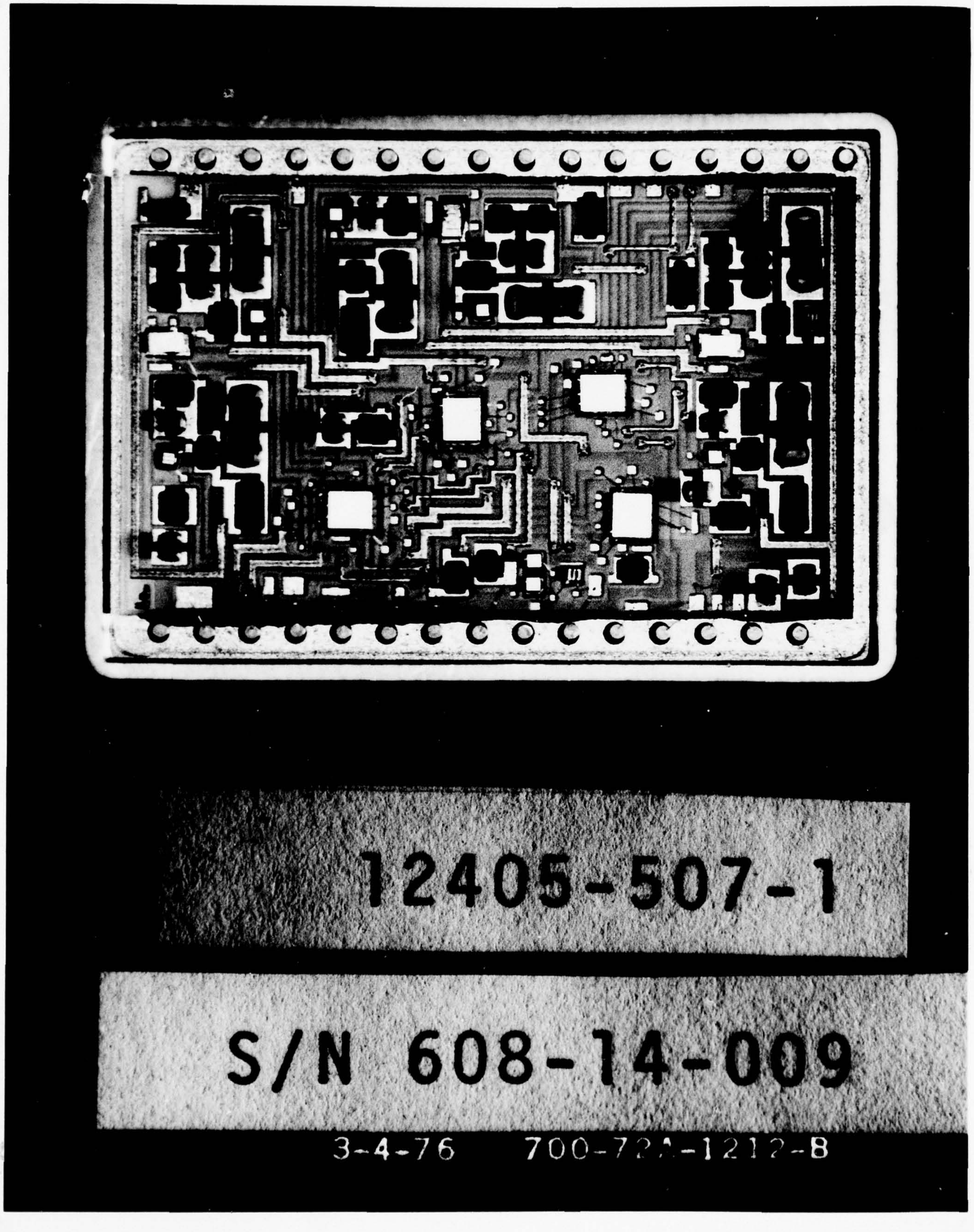

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PUB NO. VOL. NO. FIG. NO. A-4 PAGE NO. A-13

A-6

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Figure A-5. MUM Demodulator

A-7

Fig - photo ok Graphic

Figure A-6. Modulator

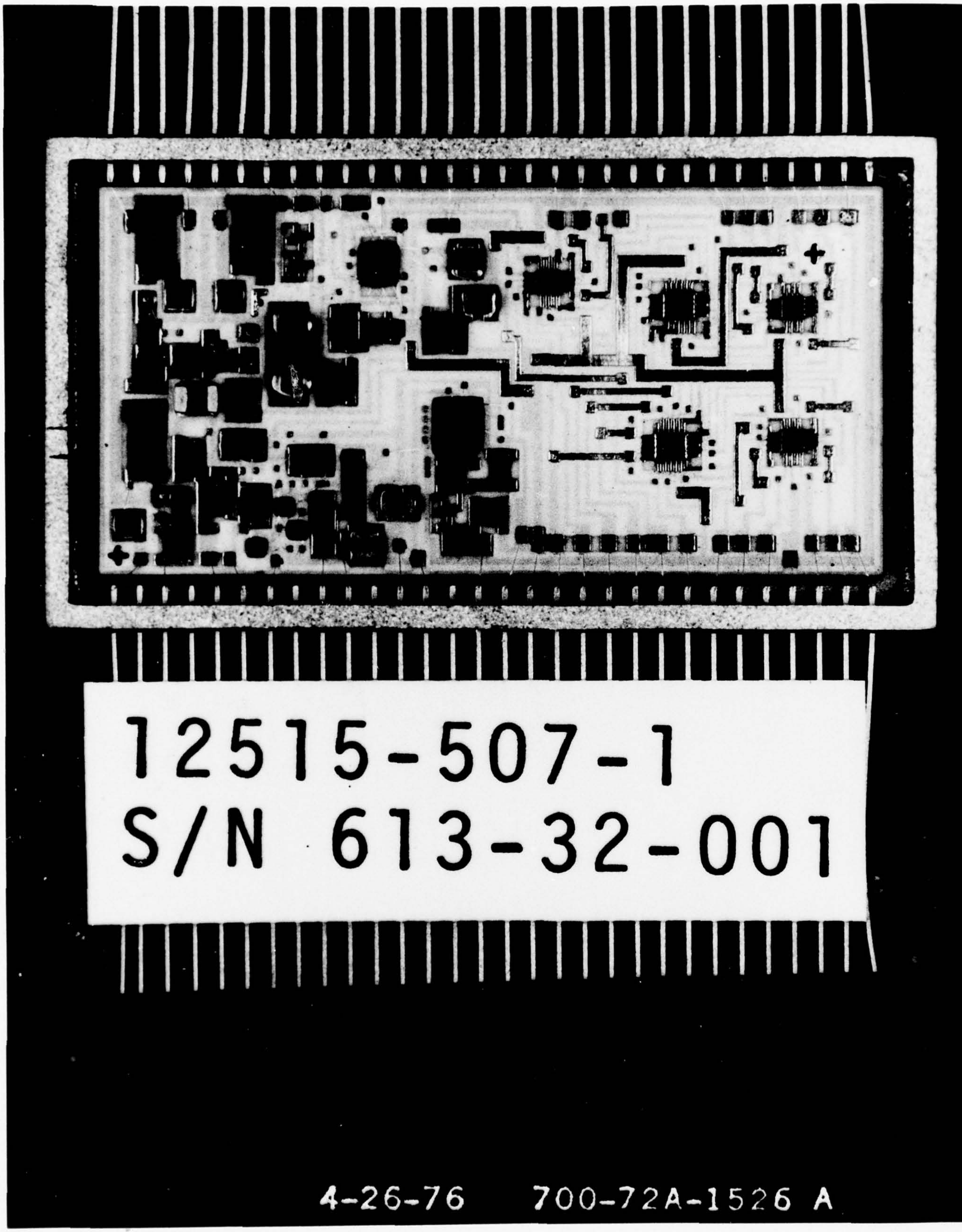

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FIG. NO. 4.5
PAGE NO. 12

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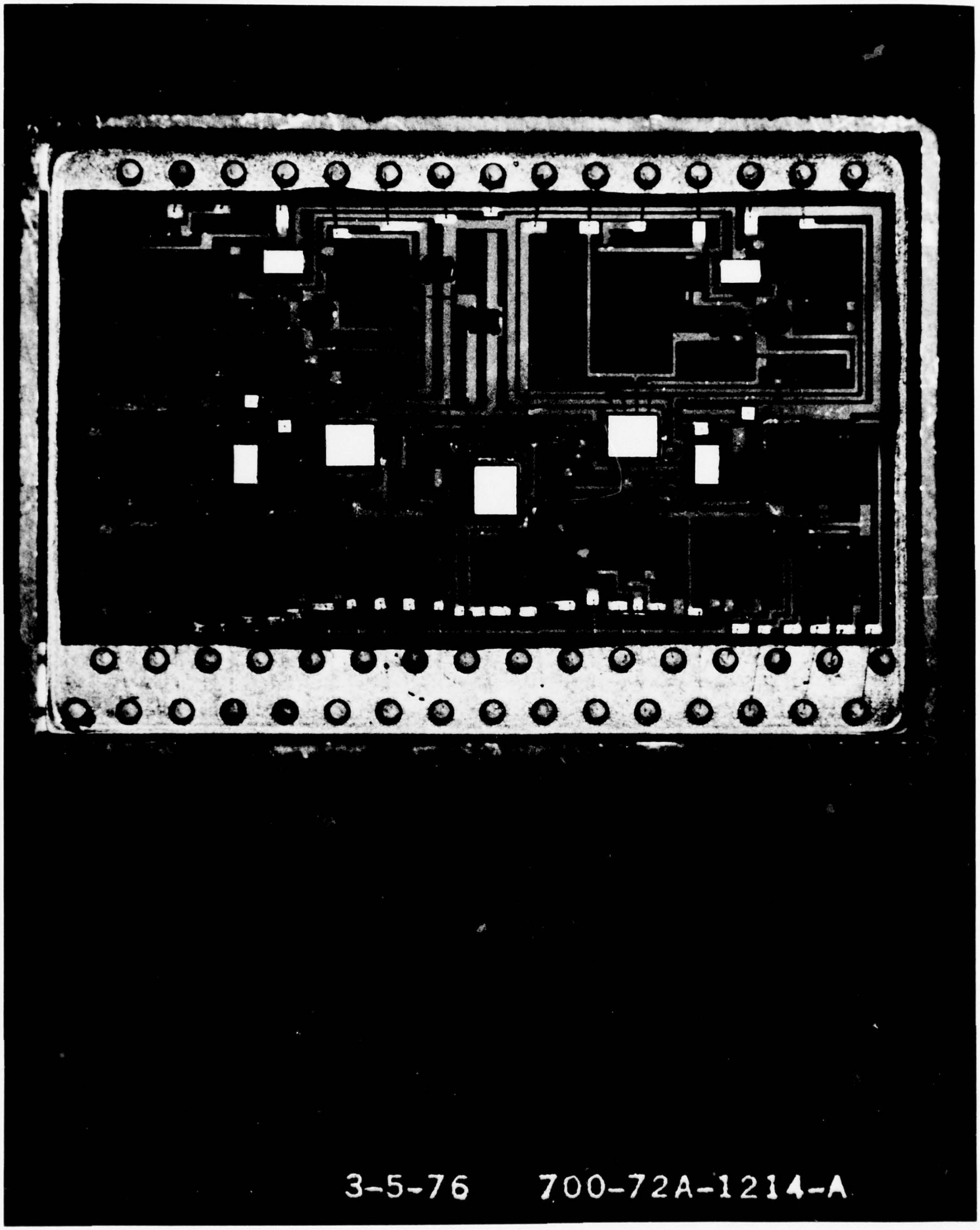

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PUB NO. VOL. NO. FIG. NO. A-6 PAGE NO. 12

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APPENDIX B

THERMAL STRESS ANALYSIS RESULTS FOR ACTIVE COMPONENTS ON HYBRID CIRCUITS

CHARGE AMP TC = 76°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
Q1 2N3439 A				*	28.1	104.1	0.25	0.452
Q2 MJC5416 B					28.1	104.1	0.25	0.452
AR1 CF2620					6.63	82.63	0.075	0.461
AR2 CF2620					6.63	82.63	0.075	0.461
AR3 LF156					6.89	82.90	0.075	0.463
CR1 BD3600	0.3374	76.34	0.001	0.342	0.6745	76.67	0.002	0.3445
CR2 BD3600	0.3374	76.34	0.001	0.342	0.6745	76.67	0.002	0.3445
CR3 BD3600	0.3589	76.36	0.001	0.342	0.7178	76.72	0.002	0.3448
CR4 BD3600	0.2548	76.25	0.001	0.342	0.5095	76.51	0.002	0.3434
CR5 MC5639-2	0.6393	76.64	0.001	0.344	1.28	77.28	0.002	0.3485
CR6 MC5639-2	0.6394	76.64	0.001	0.344	1.28	77.28	0.002	0.3485
CR7 BD3600	0.1952	76.20	0.001	0.341	0.3905	76.39	0.002	0.3426
CR8 BD3600	0.3373	76.34	0.001	0.342	0.6745	76.67	0.002	0.3445
CR9 BD3600	0.1756	76.18	0.001	0.341	0.3512	76.35	0.002	0.3423
CR10 BD3600	0.1756	76.18	0.001	0.341	0.3512	76.35	0.002	0.3423

SAMPLE & HOLD GAP TC = 68°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
AR1 CF2620	5.091	73.09	0.090	0.385	7.015	75.01	0.124	0.4001
AR2 CF2620	4.554	72.56	0.090	0.380	6.2774	74.28	0.124	0.3942
AR3 CF2620	4.554	72.56	0.090	0.380	6.2744	74.28	0.124	0.3942
AR4 CF2620	4.554	72.56	0.090	0.380	6.2744	74.28	0.124	0.3942
AR5 LF156	5.415	73.41	0.090	0.387	7.46	75.46	0.124	0.4037
Z1 CD4053 BH	0.06	68.06	0.002	0.345	0.09	68.09	0.003	0.3447
Z2 CD4053 BH	0.06	68.06	0.002	0.345	0.09	68.09	0.003	0.3447

***This data not available for nominal but since worst case T_J stress is less than 0.5, the nominal is also less than 0.5. Reliability guidelines recommend stress ratios less than 0.5 for nominal and 0.75 for worst case.**

50 KHZ BUFFER/EMA POWER SUPPLY TC = 65°C

Component Name	Nominal Case ΔT	Nominal Case T_J	Nominal Case DP	Nominal T_J Stress	Worst Case ΔT	Worst Case T_J	Worst Case DP	Worst Case T_J Stress
Q1 B2T2222A	0.0932	65.93	0.002	0.234	1.864	66.86	0.004	0.2392
Q2 B2T2222A	0.736	65.74	0.002	0.233	1.473	66.47	0.004	0.2370
Q3 B2T3725B	1.667	66.67	0.013	0.238	1.846	66.85	0.015	0.2391
Q4 B2T3725B	1.667	66.67	0.013	0.238	1.846	66.85	0.015	0.2391
Z1 LS03	0.748	65.75	0.008	0.320	1.122	66.12	0.012	0.3290
CR1 BD3600	0.439	65.44	0.001	0.270	0.878	65.88	0.002	0.2792
CR2 BD3600	0.382	65.38	0.001	0.270	0.763	65.76	0.002	0.2717
CR3 BD3600	0.382	65.38	0.001	0.270	1.908	66.91	0.005	0.2794
CR4 BD3600	0.382	65.38	0.001	0.270	1.908	66.91	0.005	0.2794
CR5 BD3600	0.382	65.38	0.001	0.270	1.908	66.91	0.005	0.2794
CR6 BD3600	0.382	65.38	0.001	0.270	1.908	66.91	0.005	0.2794
CR7 BD3600	0.382	65.38	0.001	0.270	1.908	66.91	0.005	0.2794
CR8 BD3600	0.382	65.38	0.001	0.270	1.908	66.91	0.005	0.2794
CR9 BD3600	0.382	65.38	0.001	0.270	1.908	66.91	0.005	0.2794
CR10 BD3600	0.382	65.38	0.001	0.270	1.908	66.91	0.005	0.2794
CR11 BD3600	0.382	65.38	0.001	0.270	1.908	66.91	0.005	0.2794
CR12 BD3600	0.382	65.38	0.001	0.270	1.908	66.91	0.005	0.2794
CR13 BD3600	0.382	65.38	0.001	0.270	1.908	66.91	0.005	0.2794
CR14 BD3600	0.382	65.38	0.001	0.270	1.908	66.91	0.005	0.2794
AR1 MC1538	8.68	73.68	0.151	0.389	21.67	86.67	0.377	0.4934
AR2 MC1538	8.68	73.68	0.151	0.389	21.67	86.67	0.377	0.4934
AR3 MC1538	8.68	73.68	0.151	0.389	21.67	86.67	0.377	0.4934
AR4 MC1538	9.73	74.73	0.151	0.399	24.30	89.30	0.377	0.5144

SERVO NETWORK TC = 68°C

Component Name	Nominal Case ΔT	Nominal Case T_J	Nominal Case DP	Nominal T_J Stress	Worst Case ΔT	Worst Case T_J	Worst Case DP	Worst Case T_J Stress
AR1 LF156	3.51	71.51	0.060	0.372	4.684	72.62	0.080	0.3814
Z1 CD4053 BH	0.06	68.06	0.002	0.345	0.09	68.09	0.003	0.3447
Z2 CD4053 BH	0.06	68.06	0.002	0.345	0.09	68.09	0.003	0.3447
Z3 CD4053 BH	0.06	68.06	0.002	0.345	0.09	68.09	0.003	0.3447
Z4 CD4053 BH	0.06	68.06	0.002	0.345	0.09	68.09	0.003	0.3447

TEMP CONTROLLER TC = 65°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
AR1 RM4136	1.8815	66.88	0.053	0.335	3.0175	68.06	0.085	0.3442
AR2 RM4136	1.8815	66.88	0.053	0.335	3.0175	68.02	0.085	0.3442
AR3 RM4136	1.8815	66.88	0.053	0.335	3.0175	68.02	0.085	0.3442
AR4 RM4136	1.8815	66.88	0.053	0.335	3.0175	68.02	0.085	0.3442
AR5 RM4131	0.5496	65.55	0.008	0.321	0.9618	65.96	0.014	0.3277
Z1 LS175	1.935	66.94	0.045	0.336	3.569	68.57	0.083	0.3486
Z2 LS175	1.935	66.94	0.045	0.336	3.569	68.57	0.083	0.3486
Z3 LS04	0.5291	65.53	0.012	0.324	0.5732	65.57	0.013	0.3246
Z4 DM78L12	0.3555	65.36	0.005	0.323	1.0665	66.07	0.015	0.3286
CR1 BD3600	0.2114	65.21	0.001	0.268	0.4228	65.43	0.002	0.2695
CR2 BD3600	0.2114	65.21	0.001	0.268	0.4228	65.43	0.002	0.2695
CR3 BD3600	0.2114	65.21	0.001	0.268	0.4228	65.43	0.002	0.2695
CR4 BD3600	0.2114	65.21	0.001	0.268	0.4228	65.43	0.002	0.2695
CR5 BD3600	0.2114	65.21	0.001	0.268	0.4228	65.43	0.002	0.2695
CR6 BD3600	0.2114	65.21	0.001	0.268	0.4228	65.43	0.002	0.2695
CR7 BD3600	0.2114	65.21	0.001	0.268	0.4228	65.43	0.002	0.2695
CR8 BD3600	0.2114	65.21	0.001	0.268	0.4228	65.43	0.002	0.2695

DIFF AMP/NOTCH FILTER TC = 68°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
AR1 LF156	6.65	74.65	0.120	0.397	9.31	77.31	0.168	0.4185
AR2 LF156	6.65	74.65	0.120	0.397	9.31	77.31	0.168	0.4185
AR3 LF156	7.45	75.45	0.120	0.402	10.43	78.43	0.168	0.4274
AR4 LF156	8.55	76.55	0.120	0.412	11.90	79.90	0.168	0.4392
AR5 LF156	8.55	76.55	0.120	0.412	11.90	79.90	0.168	0.4392
AR6 LF156	6.65	74.65	0.120	0.397	9.31	77.31	0.168	0.4185

SEQUENCER NO. 1 TC = 68°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
Z1 LS08	0.7989	68.8	0.017	0.350	1.081	69.08	0.023	0.3526
Z2 LS175	1.935	69.94	0.045	0.3595	3.569	71.57	0.083	0.3726
Z3 LS175	1.935	69.94	0.045	0.3595	3.569	71.57	0.083	0.3726
Z4 LS174	3.555	71.56	0.065	0.3725	6.6187	74.62	0.121	0.3970
Z5 LS08	0.8164	68.82	0.017	0.3506	1.105	69.10	0.023	0.3528
Z6 LS04	0.5350	68.54	0.012	0.3483	0.5796	68.58	0.013	0.3486
Z7 LS10	0.3342	68.33	0.006	0.3466	0.390	68.39	0.007	0.3471
Z8 LS20	0.2228	68.22	0.004	0.3458	0.2785	68.28	0.005	0.3462
Z9 LS08	0.7989	68.8	0.017	0.3504	1.081	69.08	0.023	0.3526
Z10 5407	6.365	74.37	0.125	0.395	7.025	75.03	0.138	0.4002
Z11 LS00	0.3842	68.38	0.008	0.347	0.4322	68.43	0.009	0.3474
Z12 5407	6.365	74.37	0.125	0.395	7.025	75.03	0.138	0.4002

SEQUENCER NO. 2 TC = 68°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
Z1 LS04Y	1.781	69.78	0.024	0.358	2.524	70.52	0.034	0.3642
Z2 LS08Y	0.692	68.69	0.009	0.3495	5.459	73.46	0.071	0.3877
Z3 LS04Y	1.781	69.78	0.024	0.358	2.524	70.52	0.034	0.3642
Z4 LS10Y	0.2307	68.23	0.003	0.3458	0.4613	68.46	0.006	0.3477
Z5 LS00Y	0.2307	68.23	0.003	0.3458	0.4613	68.46	0.006	0.3477
Z6 L193Y	1.208	69.21	0.043	0.354	2.332	70.33	0.083	0.3626
Z7 L193Y	1.208	69.21	0.043	0.354	2.332	70.33	0.083	0.3626
Z8 L193Y	1.208	69.21	0.043	0.354	2.332	70.33	0.083	0.3626
Z9 L193Y	1.208	69.21	0.043	0.354	2.332	70.33	0.083	0.3626
Z10 LS112Y	5.268	73.27	0.120	0.386	12.116	80.12	0.276	0.4410

SPIN MOTOR PREAMP & LOGIC TC = 70°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
AR1 CF2620	4.776	74.78	0.090	0.398	6.587	76.59	0.124	0.413
AR2 CF2620	4.776	74.78	0.090	0.398	6.587	76.59	0.124	0.413
AR3 CF2620	4.776	74.78	0.090	0.398	6.587	76.59	0.124	0.413
Z1 CD4053 BH	0.0618	70.06	0.002	0.3605	0.0927	70.09	0.003	0.3607
Z2 CD4053 BH	0.0618	70.06	0.002	0.3605	0.0927	70.09	0.003	0.3607
Z3 LS00	0.3939	70.39	0.008	0.363	0.4431	70.44	0.009	0.364
Z4 LS00	0.3822	70.38	0.008	0.363	0.4300	70.43	0.009	0.364
Z5 LS08	0.8613	70.86	0.017	0.3669	1.165	71.17	0.023	0.3694
Z6 LS08	0.8613	70.86	0.017	0.3669	1.165	71.17	0.023	0.3694
Z7 LS04	0.6080	70.61	0.012	0.3649	0.6587	70.66	0.013	0.3653
Z8 LS03	0.3822	70.38	0.008	0.3631	0.4300	70.43	0.009	0.3637
Z9 DM78L12	0.1545	70.15	0.005	0.361	0.4635	70.46	0.015	0.3637
Q1 2N2222	0.5137	70.51	0.002	0.260	23.12	93.12	0.090	0.3893
Q2 2N2222	0.3570	70.36	0.002	0.2592	16.06	86.06	0.090	0.3489
Q3 2N2222	0.3840	70.38	0.002	0.3631	17.28	87.28	0.090	0.3559
Q4 2N2222	0.5137	70.15	0.002	0.258	23.12	93.12	0.090	0.3893

SPIN MOTOR CONTROL TC = 65°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
AR1 RM4136	1.8815	66.88	0.053	0.335	3.0175	68.02	0.085	0.3442
AR2 RM4136	1.8815	66.88	0.053	0.335	3.0175	68.02	0.085	0.3442
AR3 RM4136	1.8815	66.88	0.053	0.335	3.0175	68.02	0.085	0.3442
Z1 CD4053 BH	0.0618	65.06	0.002	0.3205	0.0927	65.09	0.003	0.3207
Z2 CD4053 BH	0.0618	65.06	0.002	0.3205	0.0927	65.09	0.003	0.3207
Z3 CD4053 BH	0.0618	65.06	0.002	0.3205	0.0927	65.09	0.003	0.3207
Z4 CD4053 BH	0.0618	65.06	0.002	0.3205	0.0927	65.09	0.003	0.3207
Z5 CD4053 BH	0.0618	65.06	0.002	0.3205	0.0927	65.09	0.003	0.3207
Z6 DM78L12	0.3555	65.36	0.005	0.3229	1.0665	66.07	0.015	0.3286

EMA SIGNAL FILTER TC = 65°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
AR1 CF2620	4.56	69.56	0.090	0.357	5.86	70.86	0.124	0.3669
AR2 LF156	3.33	68.33	0.060	0.347	4.43	69.43	0.080	0.3554
Z1 DM78L12	0.70	65.70	0.010	0.326	1.12	66.12	0.0159	0.3290
Z2 CD4053 BH	0.60	65.06	0.002	0.3205	0.09	65.09	0.003	0.3207
Z3 LS08	1.396	66.40	0.017	0.3312	3.614	68.61	0.044	0.3489
Z4 LS08	1.396	66.40	0.017	0.3312	3.614	68.61	0.044	0.3489
Z5 LS08	1.396	66.04	0.017	0.3312	3.614	68.61	0.044	0.3489
Z6 LS08	1.396	66.40	0.017	0.3312	3.614	68.61	0.044	0.3489

PRECISION CRYSTAL OSCILLATOR/GAP MONITOR TC = 65°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
Z1 LS04	2.889	67.89	0.012	0.3431	5.417	70.42	0.0225	0.3634
Z2 LS112	0.88	65.88	0.020	0.327	1.76	66.76	0.040	0.3341
Z3 LS163	3.74	68.74	0.100	0.3499	6.36	71.36	0.170	0.3709
Z4 CD4053 BH	0.06	65.06	0.002	0.3205	0.09	65.09	0.003	0.3207
AR1 LF156	3.33	68.33	0.060	0.3466	4.43	69.43	0.080	0.3554
AR2 LF156	3.33	68.33	0.060	0.3466	4.43	69.43	0.080	0.3554
Q1 B2T918	2.791	67.79	0.012	0.2445	3.489	68.49	0.015	0.2485
Q2 B2T918	6.978	71.98	0.030	0.2685	8.141	73.14	0.035	0.2751

MUM DEMODULATOR TC = 65°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
AR1 RM4131	3.219	68.22	0.0225	0.3458	4.29	69.29	0.030	0.3543
AR2 RM4131	3.219	68.22	0.0225	0.3458	4.29	69.29	0.030	0.3543
AR3 RM4131	3.219	68.22	0.0225	0.3458	4.29	69.29	0.030	0.3543
Z1 CD4053 BH	0.06	65.06	0.002	0.3205	0.09	65.09	0.003	0.3207
Z2 CD4053 BH	0.06	65.06	0.002	0.3205	0.09	65.09	0.003	0.3207
Z3 CD4053 BH	0.06	65.06	0.002	0.3205	0.09	65.09	0.003	0.3207
Z4 CD4053 BH	0.06	65.06	0.002	0.3205	0.09	65.09	0.003	0.3207
Z5 DM78L12	1.05	66.05	0.015	0.3284	2.53	67.53	0.036	0.3402

SYNCHRO DAC

TC = 75°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
AR1 RM4136	7.455	82.46	0.210	0.4597	12.075	87.08	0.340	0.4966
AR2 RM4136	7.455	82.46	0.210	0.4597	12.075	87.08	0.340	0.4966
Z1 AD7522	0.3510	75.35	0.015	0.4028	0.702	75.70	0.030	0.4056
Z2 AD7522	0.3510	75.35	0.015	0.4028	0.702	75.70	0.030	0.4056
Z3 AD7522	0.3510	75.35	0.015	0.4028	0.702	75.70	0.030	0.4056
Z4 AD7522	0.3510	72.02	0.015	0.4002	0.702	75.70	0.030	0.4056

DAC AMP

TC = 75°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
AR1 RM4136	7.455	82.46	0.210	0.4597	12.075	87.08	0.340	0.4966
AR2 RM4136	7.455	82.46	0.210	0.4597	12.075	87.08	0.340	0.4966
AR3 RM4136	7.455	82.46	0.210	0.4597	12.075	87.08	0.340	0.4966
AR4 RM4136	7.455	82.46	0.210	0.4597	12.075	87.08	0.340	0.4966
Z1 CD4053 BH	0.0618	75.06	0.002	0.4005	0.0927	75.09	0.003	0.4007

SYNCHRO BITE

TC = 75°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
AR1 RM4136	1.8815	76.88	0.053	0.415	3.0175	78.02	0.085	0.4242
AR2 RM4136	1.8815	76.88	0.053	0.415	3.0175	78.02	0.085	0.4242
AR2 RM4136	1.8815	76.88	0.053	0.415	3.0175	78.02	0.085	0.4242
Z1 CD4053 BH	0.0618	75.06	0.002	0.4005	0.0927	75.09	0.003	0.4007

SUSPENSION TIMING GENERATOR TC = 70°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
Z1 LS04	1.112	71.11	0.024	0.3689	1.576	71.58	0.034	0.3726
Z2 LS163	3.553	73.56	0.095	0.3885	5.984	75.99	0.160	0.408
Z3 LS163	3.553	73.56	0.095	0.3885	5.984	75.99	0.160	0.408
Z4 LS112	0.748	70.75	0.020	0.366	1.496	71.50	0.040	0.372
Z5 LS00	0.6199	70.62	0.003	0.365	4.89	74.89	0.006	0.3991
Z6 LS10	0.448	70.45	0.003	0.3636	3.534	73.53	0.006	0.3882
Z7 LS08	0.6997	70.70	0.009	0.3652	5.52	75.52	0.071	0.4046
Z8 LS04	1.781	71.78	0.024	0.3742	2.524	72.52	0.034	0.3802
Z9 LS21	0.2244	70.22	0.006	0.3618	0.4114	70.41	0.011	0.363
Z10 LS21	0.2244	70.22	0.006	0.3618	0.4114	70.41	0.011	0.363
Z11 LS112	0.748	70.75	0.020	0.3641	1.496	71.50	0.040	0.372
Z12 LS112	0.748	70.75	0.020	0.3641	1.496	71.50	0.040	0.372
Z13 LS04	1.139	71.14	0.024	0.3691	1.614	71.61	0.034	0.3729
Z14 5407	0.1122	70.11	0.003	0.3689	0.2244	70.22	0.006	0.3618

MULTIPLEXER TC = 70°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
AR1 LF156	6.648	76.65	0.120	0.413	9.307	79.31	0.168	0.4345
Z1 CF506A	4.5	74.5	0.036	0.396	15.0	85.0	0.120	0.480
Z3 CF506A	4.5	74.5	0.036	0.396	15.0	85.0	0.120	0.480

A/D CONVERTER TC = 68°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
AR1 CMP-01	4.664	72.67	0.078	0.3814	7.295	75.3	0.122	0.4024
AR2 CF2620	3.643	71.643	0.072	0.3731	4.503	72.5	0.089	0.380
Z1 65008	1.745	69.75	0.233	0.358	1.745	69.75	0.233	0.358
Z2 D139	4.670	72.67	0.042	0.3814	4.670	72.67	0.042	0.3814
Z3 10005	11.866	79.87	0.469	0.439	11.866	79.87	0.469	0.439
CR1 BD3600	4.304	72.304	0.0098	0.3154	4.304	72.304	0.0098	0.3154

MUM DEMODULATOR SAMPLE AND HOLD TC = 65°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
AR1 LF156	4.577	69.58	0.060	0.3566	6.102	71.1	0.080	0.368
AR2 LF156	3.726	68.73	0.060	0.3498	4.968	69.97	0.080	0.3598
AR3 LF156	3.726	68.73	0.060	0.3498	4.968	69.97	0.080	0.3598
AR4 LF156	4.59	69.96	0.060	0.3597	6.612	71.61	0.080	0.3728
AR5 LF156	3.33	68.33	0.060	0.3466	4.43	69.43	0.080	0.3554
AR6 LF156	3.513	68.51	0.060	0.3481	4.684	69.68	0.080	0.3574
Z1 CD4053 BH	0.15	65.15	0.005	0.3212	0.31	65.31	0.010	0.3225
Z2 CD4053 BH	0.15	65.15	0.005	0.3212	0.31	65.31	0.010	0.3225
Z3 CD4053 BH	0.15	65.17	0.005	0.3214	0.34	65.34	0.010	0.3227
Z4 CD4053 BH	0.15	65.15	0.005	0.3212	0.31	65.31	0.010	0.3225

SYNCHRO REF GENERATOR TC = 75°C

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
AR1 LF156				*	4.6	80	0.076	0.44
AR2 LF156					4.6	80	0.076	0.44
Z1 SN54L123					5.8	81	0.115	0.45
Z2 CD4053					0	75	0.001	0.4
Z3, 6, 7 BL54LS04					0	75	0.012	0.4
Z4, 5 BL54LS138					0	75	0.032	0.4
CR1, 2, 3 MZC3.9A5					0	75	0.001	0.4
CR4, 5 BD3600					0	75	0.001	0.4
Q1, 2, 3 FT5416B					3.2	78	0.080	0.42
Q4 B2T2222A					0	75	0.001	0.4

*This data not available for nominal but since worst case T_J stress is less than 0.5, the nominal is also less than 0.5. Reliability guidelines recommend stress ratios less than 0.5 for nominal and 0.75 for worst case.

MODULATOR $T_C = 71^oC$

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
DZ1 MZC3.9A5	-	71	-	-	39	110	52.1	0.566
DZ2 MZC3.9A5	-	71	-	-	39	110	52.1	0.566
AR1 LF156	7.3	78.3	98	0.430	7.3	78.3	98.0	0.430
AR2 LF156	6.8	77.8	91	0.426	6.8	77.8	91.0	0.426
AR3 LF156	7.3	78.3	98	0.430	7.3	78.3	98.0	0.430
AR4 LF156	6.8	77.8	91	0.426	6.8	77.8	91.0	0.426
Z3 CD4054B	-	71	0.02	0.46	-	71	0.02	0.46
Z6 CD4053B	-	71	0.02	0.46	-	71	0.02	0.46
Z1 CD4053B	-	71	0.02	0.46	-	71	0.05	0.46
DZ3 MZC3.9A5	-	71	-	-	14.3	85.3	52.1	0.402
DZ4 MZC3.9A5	-	71	-	-	14.3	85.3	52.1	0.402

DC REF & PRELOAD MODULATOR $T_C = 71^oC$

Component Name	Nominal Case			Nominal T_J Stress	Worst Case			Worst Case T_J Stress
	ΔT	T_J	DP		ΔT	T_J	DP	
Q1 2N2907A				*	27.8	98.8	312.0	0.409
DZ1 MZC3.9A5					18.1	89.1	68.0	0.427
Z1 CD4053B					0.003	71.0	0.06	0.460
Z2 CD4053B					0.002	71.0	0.04	0.460
A1 MCC 1538					14.0	85.3	302.0	0.482
A2 LF156					5.9	77.1	81.0	0.417
A3 LF156					2.8	83.9	39.0	0.391
A4 LF156					5.8	77.0	80.0	0.416
A5 LF156					5.7	76.9	79.0	0.415
A6 MCC1538					14.0	85.3	302.0	0.482
A7 LF156					5.7	76.9	79.0	0.415

*This data not available for nominal but since worst case T_J stress is less than 0.5, the nominal is also less than 0.5. Reliability guidelines recommend stress ratios less than 0.5 for nominal and 0.75 for worst case.

SYNCHRO BUFFER AMPLIFIER

	Nominal				Worst Case			
Amplifier (SL25548)	ΔT	T_J	DP	Stress	ΔT	T_J	DP	Stress
AR1	1.992	74.992	0.68	0.400	14.650	87.650	5	0.501
AR2	1.992	74.992	0.68	0.400	14.650	87.650	5	0.501
AR3	12.306	85.306	4.2	0.482	29.300	102.300	10	0.618
AR4	12.306	85.306	4.2	0.482	29.300	102.300	10	0.618

APPENDIX C. HYBRID, MODULE, AND TRANSFORMER FUNCTIONAL TEST SPECIFICATIONS

This appendix provides a list of functional test specifications which were written for hybrid, module and transformer functional test. The parameters in the functional test specifications have been derived from the detail design specifications.

TABLE C-1. MODULE FUNCTIONAL TEST SPECIFICATIONS

Specification Number	Title
AL01073	Suspension and MUM Electronics, Autonetics Drawing Number 12302-507; Functional Test For
AL01074	Timing and Sequencing Module, Autonetics Drawing Number 12305-507; Functional Test For
AL01075	Signal Generator and Memory Module, Autonetics Drawing Number 12310-507; Functional Test For
AL01076	Converter Electronics Module, Autonetics Drawing Number 12330-507; Functional Test For
AL01077	Power Supply Number 1, Autonetics Drawing Number 12345-507; Functional Test For
AL01078	Power Supply Number 2 and 3, Autonetics Drawing Number 12356-507; Functional Test For
AL01079	High Voltage Switch, Autonetics Drawing Number 12360-507; Functional Test For
AL01088	MICRON Central Processor Unit, P/N 14219-501, Acceptance Test For
AL01090	MICRON Processor Input Output; Autonetics Part Number 15390-501-1, Acceptance Test for
AL01202	Charge Amplifier Assembly, Autonetics Drawing Number 12725-507; Functional Test For
AL01203	Spin Motor Electronics Module, Autonetics Drawing Number 12753-507; Functional Test For
AL80281	MICRON Data Terminal Unit; Autonetics Part Number 12335-507, Operating Instructions For

TABLE C-2. HYBRID FUNCTIONAL TEST SPECIFICATIONS

Specification Number	Title
AL00985	Charge Amplifier, Autonetics Drawing Number 12400-507; Functional Test For
AL00986	Sample and Mold/Gap Summation, Autonetics Drawing Number 12520-507; Functional Test For
AL00987	Servo Network, Autonetics Drawing Number 12405-507; Functional Test For
AL00988	Differential Amplifier and Notch Filter, Autonetics Drawing Number 12410-507; Functional Test For
AL00989	Modulator, Autonetics Drawing Number 12425-507; Functional Test For
AL00990	Multiplexer, Autonetics Drawing Number 12430-507; Functional Test For
AL00991	MUM Demodulator, Autonetics Drawing Number 12415-507; Functional Test For
AL00992	MUM Democulator Filter, Autonetics Drawing Number 12420-507; Functional Test For
AL00993	MUM Demodulator Sample and Hold, Autonetics Drawing Number 12435-507; Functional Test For
AL00994	Suspension Timing Generator, Autonetics Drawing Number 12445-507; Functional Test For
AL00995	DC Reference and Preload Modulator, Autonetics Drawing Number 12480-507; Functional Test For
AL00996	Precision Crystal Oscillator and Gap Monitor, Autonetics Drawing Number 12470-507; Functional Test For
AL00997	Sequencer Number 1, Autonetics Drawing Number 12450-507; Functional Test For
AL00998	Sequencer Number 2, Autonetics Drawing Number 12455-507; Functional Test For

TABLE C-2. (Cont)

Specification Number	Title
AL00999	50 kHz Buffer and EMA Power Supply, Autonetics Drawing Number 12475-507; Functional Test For
AL01000	EMA Signal Filter, Autonetics Drawing Number 12495-507; Functional Test For
AL01001	A/D Converter, Autonetics Drawing Number 12440-507; Functional Test For
AL01002	Spin Motor Controller, Autonetics Drawing Number 12485-507; Functional Test For
AL01003	Temperature Controller, Autonetics Drawing Number 12490-507; Functional Test For
AL01004	Spin Motor Power Pre-Amplifier and Logic, Autonetics Drawing Number 12525-507; Functional Test For
AL01006	Synchro Buffer Amplifier, Autonetics Drawing Number 12510-507; Functional Test For
AL01007	Synchro Reference Generator, Autonetics Drawing Number 12515-507; Functional Test For
AL01008	Synchro Bite, Autonetics Drawing Number 12505-507; Functional Test For
AL01009	Synchro DAC, Autonetics Drawing Number 12545-507; Functional Test For
AL01063	DAC Amplifier, Autonetics Drawing Number 12560-507; Functional Test For
AL01064	Ladder Network, Autonetics Drawing Number 12565-507; Functional Test For
AL80294	MICRON Hybrid Decoder, Autonetics Part Number 12540-507-1; Operating Instructions For
AL80295	MICRON Hybrid Encoder, Autonetics Part Number 12535-507-1; Operating Instructions For
AL80296	MICRON Hybrid Transmitter/Receiver, Autonetics Part Number 12530-507-1; Operating Instructions For

TABLE C-3. TRANSFORMER FUNCTIONAL TEST SPECIFICATIONS

Specification Number	Title
AL01055	Transformer, Power, Step-up, Autonetics Part Number 13304-404-1; Functional Test For
AL01056	Transformer, Power, Step-up and Step-down, Autonetics Part Numbers 13313-404-1 and 13321-404-1; Functional Test For
AL01057	Transformer, Power, Isolation, Autonetics Part Number 13308-404-1; Functional Test For
AL01058	Transformer, Power, Step-down, Autonetics Part Number 13317-404-1; Functional Test For
AL01059	Transformer, Pulse, Autonetics Part Number 20321-404-1; Functional Test For
AL01060	Reactor, Autonetics Part Number 36317-404-1; Functional Test For
AL01061	Transformer, Saturable, Autonetics Part Number 40426-404-1; Functional Test For

APPENDIX D. PRECISION THIN FILM RESISTOR REQUIREMENTS AND PERFORMANCE TESTS

There are a number of EPM hybrid substrates which contain resistors which require good tracking stability to maintain system calibration. The estimated requirements are summarized in Table D-1.

Test data has been taken on a limited sample of Halex Inc. resistors and Collins Radio resistors. Halex resistors are utilized for precision electronics for the FPM system. The preproduction system uses Collins Radio resistors.

Two networks (H01 and H02) of Halex resistors and three networks (C01, C02 and C03) of Collins resistors were packaged, sealed and initial measurements were made. Periodic resistor measurements were then made after the resistors were stored in an 85°C environment. Collins and Halex resistors meet the stability requirements, as shown in Table D-2.

It is estimated that the system will have about 40 hr of operation per month when in the field, or 480 hr per year. The temperature of the resistors in the system with power on will be between 65°C and 70°C. It is estimated that the rate of change of resistors doubles for every 10°C. At room temperature with power off (25°C) the rate of change would be

$$2^{-\left(\frac{85-25}{10}\right)} = 1/64$$

the rate of change at 85°C. Therefore the data obtained for 1020 hr at 85°C indicate the resistors should have adequate stability for two years if all of the above assumptions are true. Further tests will be conducted with power on to determine if there is a difference for these conditions.

TABLE D-1. MICRON PRECISION RESISTOR REQUIREMENTS

Part Number	Title	TCR Absolute / ^{o}C (ppm)	TCR Tracking / ^{o}C (ppm)	Ratio Tracking Stability/Year
12400-507	Charge Amplifier	$\leq \pm 150$	10 ± 5	20 ppm @ 75°C
12410-507	Diff Amp/Notch Filter	$\leq \pm 150$	10 ± 5	33 ppm @ 70°C
12415-507	MUM Demodulator	$\leq \pm 150$	10 ± 5	20 ppm @ 70°C
12420-507	MUM Demodulator Filter	$\leq \pm 150$	10 ± 5	20 ppm @ 70°C
12425-507	Modulator	$\leq \pm 150$	100 ± 50	100 ppm @ 70°C
12430-507	Multiplexer	$\leq \pm 150$	35 ± 17.5	Ratio of 650 ppm Absolute of 150 ppm @ 70°C
12435-507	MUM Demodulator S&H	$\leq \pm 150$	10 ± 5	20 ppm @ 70°C
12480-507	DC Ref & Reload Mod	$\leq \pm 150$	10 ± 5	20 ppm @ 70°C
12510-507	Synchro Buffer Amp	$\leq \pm 150$	10 ± 5	40 ppm @ 75°C
12520-507	S&H/Gap Summation	$\leq \pm 150$	100 ± 50	100 ppm @ 70°C
12545-507	Synchro DAC	$\leq \pm 150$	10 ± 5	40 ppm @ 75°C
12560-507	DAC Amp	$\leq \pm 150$	10 ± 5	40 ppm @ 75°C
12565-507	Ladder Network	$\leq \pm 150$	5 ± 2.5	25 ppm @ 70°C (Accumulated total error)

TABLE D-2. COLLINS-HALEX RESISTOR STUDY (PPM SHIFT)

		STANDARD COLLINS PROCESS 100 ohms/square				HALEX 150 ohms/square		
	Absolute R	CO1	CO2	CO3	COMB	HO1	HO2	COMB
Postseal to Post	$\overline{X}$	-57.1	-76.9	-50.7	-61.57	24.31	21.49	22.9
	Max	-50.6	-73.7	-48.5	-48.5	27.91	26.58	27.9
	Min	-60.8	-79.8	-53.8	-79.8	17.28	16.61	16.6
	σ	2.7	2.3	1.9	11.6	3.22	2.69	3.4
340 Hours at 85°C	Ratio							
	$\overline{X}$	.50	.51	- 1.2	- 0.05	0.49	- 1.90	- 0.7
	Max	5.7	5.8	5.1	5.8	10.61	5.31	10.6
	Min	- 5.0	- 5.0	- 5.7	- 5.7	-10.49	- 9.96	-10.5
	σ	2.8	3.1	2.7	3.0	4.64	2.95	4.1
	Absolute R							
Postseal to Post	$\overline{X}$	-110.8	-120	-88.9	-106.6	22.7	18.5	20.6
	Max	-105.6	-116.4	-77.9	- 77.9	29.2	20.6	29.2
	Min	-114.7	-123.6	-93.8	-123.6	19.3	16.0	15.9
	σ	2.58	2.02	4.4	13.58	3.1	2.2	3.4
1020 Hours at 85°C	Ratio							
	$\overline{X}$	0.3	- 0.9	- 1.5	- 0.7	0.7	0.02	0.4
	Max	9.1	3.8	15.3	15.0	10.5	5.0	10.5
	Min	- 5.7	- 6.0	-15.0	-15.0	- 9.3	- 5.0	- 9.3
	σ	3.8	2.5	6.1	4.5	4.4	3.3	3.9

NOTES: All circuits built from 12420-507 artwork – MUM Demod Filter (MICRON)
Each circuit contains 12, 94K resistors designed for 150 ohms/sq each packaged in a MICRON package and sealed
Collins circuits were built using 100 ohms/sq, therefore their resistors were 63K
"Absolute R" rows are average of 12 resistors
"Ratio" rows are average of 55 ratios of the 12 resistors
"Combined" column is the total data of all substrates

X = **average change of the 12 resistors**
Max = **maximum change of the 12 resistors**
Min = **minimum change of the 12 resistors**
σ = **standard deviation of the change for the 12 resistors**

APPENDIX E. FABRICATION, ASSEMBLY, AND TEST OF EPM ELECTRONIC MODULES

MODULE FAB/ASSEMBLY/TEST

A flow diagram for the fabrication, assembly and test of the electronics modules is shown in Figure E-1. All hardware has been fabricated per documented ESWA procedures. Operational Sign Off Record (OSR) books are maintained for each module type. When an operation or test is completed, it is verified by inspection, stamped and dated. Functional test data is also recorded in the OSR book at the time of functional test.

Fab Printed Circuit Board

↓

Inspection

↓

Assembly of Heaters and Heat Sinks

↓

Inspection

↓

Assemble Components

↓

Functional Test (25°C)

↓

Functional Test (-55°C)

↓

Functional Test (70°C)

↓

Burn-In (105°C for 168 hours)

Figure E-1. Flow Diagram for Fab, Assembly and Test of Modules

Blank

APPENDIX F. RESULTS AND ANALYSES OF MAGNETIC FIELD SENSITIVITY TESTS*

A magnetic coil was fabricated and installed on Test Station No. 4. The coil was mounted so that the gyro would be in the center of the coil, and the generated field would be parallel to the gyro Z-axis. The 14 holes in the mu-metal shield for feedthroughs (eight to the gyro electrodes plus six to the spin motor windings) are along the +Z axis, and the θ-shaped hole for the cavity support structure and vacuum port are along the -Z axis. From this, it might be expected that the dominant weakness in the shielding would be along the Z-axis. (This was found to be the case during Phase 1A vibration testing, in which the magnetic field levels at the gyro location on the shaker were from 20 to 55 gauss. At that time, the dominating effect was a slowdown torque on the rotor. This torque was maximum when the Z-axis was parallel to the field direction.) With the gyro removed, the magnetic field was measured by a Hall probe at the gyro location which the coil current was varied. The coil current levels at 1, 3.16 and 10 gauss were noted and used later for applying these field levels to a gyro. The magnitude of the earth's magnetic field is about 0.3 gauss in the laboratory, and this field was also present when these measurements were made. Consequently, the total applied field (earth field + coil field) will have the correct values for the orientation of the tilt table in which the coil calibration was made. The tilt table was re-oriented to apply the field at the different angles to the spin axis, so that the total applied field could differ slightly from the calibrated values at the non-calibrated orientations. However, the coil-induced field magnitudes were generally much greater than the natural field magnitude. Consequently, the results are considered reasonably accurate, especially at the higher field levels.

Magnetic sensitivities were determined by applying the magnetic field during alternate samples of either drift data or angle readout data. In this way, interpolation between the "no-field" samples could be used for removing any secular trend in the outputs. In the case of drift data, the magnetic field was "off" for 10 min, then "on" for 10 min, etc. In the case of angle readout data, the field was alternately "on" and "off" for periods of one minute, with smoothed samples recorded every 15 sec.

In the case of angle readout data, shifts of less than 0.01 milliradians could have been detected, but none were observed under any conditions - even with 10 gauss input.

In the case of drift data, definite shifts were recorded. The results are tabulated in Table F-1. These tend to support a model of "gauss-squared" sensitivity of drift rates, which is the physically derived model relationship. This relationship in the test data is demonstrated in Figure F-1, which is a log-log plot of measured rss drift rate change vs applied field strength. All the plots have a "gauss-squared" slope, with different intercepts for different angles between the applied field and the rotor spin axis. The greatest sensitivity occurred with 45 deg between the field and the spin axis. This is roughly an order of magnitude greater than the sensitivity with the spin axis parallel to the field, and a factor of three greater than the sensitivity with the spin axis normal to the field. A similar relationship would be predicted by the model, which is derived from the model for an unshielded rotor.

*The N75 activities discussed in this appendix were performed under a separate IR&D task using the N57A System. Although this activity was not performed under the MICRON contract, this discussion in included in this report since it provides additional information on the sensitivity of system performance to magnetic fields.

TABLE F-1. MAGNETIC FIELD SENSITIVITY SUMMARY, THREE GYROS:
(Spin Vector Oriented Polar, Magnetic Field Case-Fixed Along Z)

Angle Between Field and Spin Vector	Gyro Number	Change of Gyros Drift Rates Deg/Hr/Axis			Average Per Axis Sensitivity, $Deg/Hr/Gauss^2$
		1 Gauss	3.16 Gauss	10 Gauss	
0^o	A013Y	0.003	NA	0.310	
	A017Y	0.011	0.062	0.194	
	A021Y	0.003	0.015	0.049	0.0037
	Average	0.005	0.039	0.184	
45^o	A013Y	0.049	NA	2.375	
	A017Y	0.039	0.379	1.506	
	A021Y	0.029	0.291	2.219	0.0310
	Average	0.039	0.335	2.033	
90^o	A013Y	0.015	NA	0.698	
	A017Y	0.013	0.117	0.175	
	A021Y	0.008	0.082	0.543	0.0088
	Average	0.012	0.099	0.472	

An unshielded spinning rotor has a drift sensitivity to a uniform magnetic field that is modeled by the following formula:

$$\dot{\gamma} = -k\,\gamma \times (\gamma^T f)\,(\gamma \times f)$$

where

k is a proportionality constant (depending upon rotor speed and rotor bulk resistivity)

γ is a unit vector parallel to the rotor spin axis

f is the uniform magnetic field vector

x denotes a vector cross-product

The MESG is shielded, but there are gaps in the mu-metal shield that admit some z-axis component of field. Consequently, the expected drift rate due to the internal magnetic field will be approximated by a z-axis component, which is of the form

$$\dot{\gamma} = -k'\,\gamma \times \left(\gamma^T \begin{bmatrix} 0 \\ 0 \\ f_z \end{bmatrix}\right)\left(\gamma \times \begin{bmatrix} 0 \\ 0 \\ f_z \end{bmatrix}\right)$$

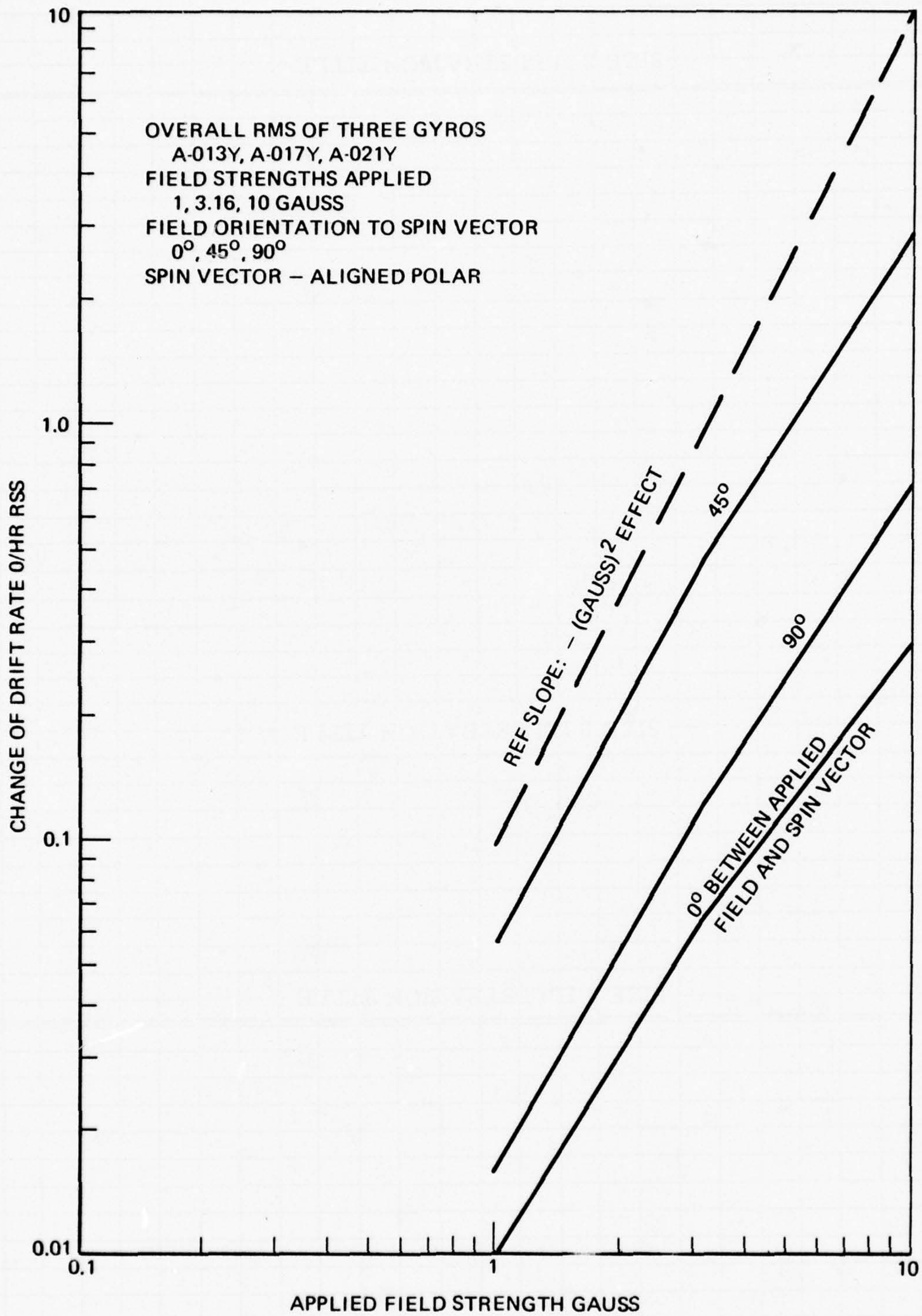


Figure F-1. Drift Rate Sensitivity to a Magnetic Field

$$= -k'\gamma \times (\gamma_z f_z) \begin{bmatrix} \gamma_y f_z \\ -\gamma_x f_z \\ 0 \end{bmatrix}$$

$$= +k' f_z^2 \begin{bmatrix} -\gamma_x \gamma_z^2 \\ -\gamma_y \gamma_z^2 \\ (\gamma_x^2 + \gamma_y^2)\gamma_z \end{bmatrix}$$

where k' now contains the attenuation factor due to the shielding for the applied field. (The actual field inside the mu-metal will probably not be uniform in direction and magnitude, but the model may serve as an approximation.) For this model, the squared drift rate will be

$$|\dot{\gamma}|^2 = (k')^2 f_z^4 \left[\gamma_x^2 \gamma_z^2 + \gamma_y^2 \gamma_z^2 + \left(\gamma_x^2 + \gamma_y^2\right)^2\right] \gamma_z^2$$

$$= (k')^2 f_z^4 \left[\left(\gamma_x^2 + \gamma_y^2\right)\left(\gamma_x^2 + \gamma_y^2 + \gamma_z^2\right)\right] \gamma_z^2$$

$$= (k')^2 f_z^4 \left(\gamma_x^2 + \gamma_y^2\right)\gamma_z^2$$

$$= (k')^2 f_z^4 \gamma_z^2 \left(1 - \gamma_z^2\right)$$

This will have its maximum value when

$$\gamma_z^2 = \frac{1}{2} \text{ and } f = \begin{bmatrix} 0 \\ 0 \\ f_z \end{bmatrix}$$

which is when the rotor spin axis is 45 deg from the ±z-axis and the total field is along z. Under these conditions, the maximum magnitude

$$|\dot{\gamma}|_{max} = \frac{1}{2} k' |f|^2 \qquad (1)$$

The rms magnitude, over all orientations of the spin axis (γ) with respect to the MESG case, will be the root-mean (RM):

$$
\left|\dot{\gamma}\right|_{rms} = k' f_z^2 \ \mathrm{RM}\left(\gamma_z^2 - \gamma_z^4\right)
$$

$$
= k' f_z^2 \sqrt{\frac{1}{3} - \frac{1}{5}}
$$

$$
= \sqrt{\frac{2}{15}} \ k' f_z^2
$$

However, the MESG case may have any orientation with respect to the external field, also. The rms over all relative orientations of the MESG with respect to the field will be

$$
\left|\dot{\gamma}\right|_{rms} = \sqrt{\frac{2}{15}} \ k' \ \mathrm{RM}\left(f_z^4\right)
$$

$$
= \sqrt{\frac{2}{15}} \ k' \left(\frac{1}{\sqrt{5}} \left|f\right|^2\right)
$$

$$
= \sqrt{\frac{2}{75}} \ k' \left|f\right|^2 \tag{2}
$$

From the measured peak sensitivity of 0.031 deg/hr/axis/gauss^2, one can infer that the experimental value of the constant k' in Eq (1) is:

$$
k' = \frac{2\left|\dot{\gamma}_{max}\right|}{\left|f\right|^2}
$$

$$
= (2)\left(\sqrt{2}\right)(0.031)
$$

$$
= 0.088
$$

(The factor of $\sqrt{2}$ is needed because the units of $\left|\dot{\gamma}\right|$ are deg/hr "radial" and those of 0.031 are deg/hr/axis.") Consequently, from Eq (2), the rms drift rate would be expected to be

$$
\frac{1}{\sqrt{2}} \left|\dot{\gamma}\right|_{rms} = \frac{1}{\sqrt{75}} (0.088) \left|f\right|^2
$$

$$
= 0.010 \left|f\right|^2
$$

The magnitude of the natural magnetic field ranges from about 0.2 to 0.7 gauss. Consequently, one would predict that the rms induced drift rates would range from 0.0004 deg/hr/axis to 0.005 deg/hr/axis.

The level of the natural magnetic field in the MICRON laboratory is about 0.3 gauss. From this, one would infer an expected rms drift rate in the order of 0.001 deg/hr/axis due to this effect. It is interesting to note that the most significant new drift model "discovered" in Phase 2A has exactly the same form as the magnetic

sensitivity model, but with the magnetic field vector "f" replaced by the gravitational field vector "g." No physical explanation of the model could be determined at that time. It now appears possible that the effect may, in fact, be a magnetic effect, because the magnetic field direction is only about 30 deg from the gravitational field direction at the laboratory.

Some additional tests were performed to determine the effect of mu-metal shield design on sensitivity. The "N57A" design for the spin motor coil assembly has an extra hole along the z-axis for a screw which fixes the motor to the top of the vacuum housing. This motor design was compared to the EPM motor design, which is without the extra z-hole. The results are tabulated in Table F-2 and summarized in Figure F-2. They indicate no dramatic reduction in sensitivity resulting from elimination of the extra z-hole.

TABLE F-2. MAGNETIC FIELD SENSITIVITY SUMMARY, EFFECT OF SPIN MOTOR SHIELDING (N57A Type: Hole Along Z Axis, EPM Type: No Hole Along "Z" Axis, Spin Vector Oriented Polar, Magnetic Field - Case-Fixed)

Magnetic Field Orientation To Spin Vector	Motor Type Shielding	Gyro Drift Rate Sensitivities Deg/Hr/Gauss^2/Axis		
		1 Gauss	3.16 Gauss	10 Gauss
0^o	N57A EPM	0.008 0.003	0.006 0.001	0.003 0.001
45^o	N57A EPM	0.045 0.029	0.038 0.029	0.020 0.022
90^o	N57A EPM	0.013 0.008	0.011 0.008	0.005 0.006

The rotor speed changes observed during the tests are tabulated in Table F-3 and summarized in Figure F-3. They show generally good agreement with the model, which would predict the maximum drag torques with the spin axis 90 deg from the field and varying as the square of the field. They also show generally close agreement in magnitude. With the spin axis 45 deg from the field direction, the model would predict as much torque in drift as in drag. The tabulated results would then relate to drifts as follows (where "$\longleftrightarrow$" means "would be equivalent to").

$$0.016 \text{ Hz/min/gauss}^2 \longleftrightarrow \frac{0.016}{2460 \text{ (Hz)}} \text{ rad/min/gauss}^2$$

$$\longleftrightarrow \frac{0.016}{(60)\ (2460)} \text{ rad/sec/gauss}^2$$

$$\longleftrightarrow \frac{(0.016)\ (2 \times 10^5)}{(60)\ (2460)} \text{ deg/hr/gauss}^2$$

$$\longleftrightarrow 0.022 \text{ deg/hr/gauss}^2$$

$$\longleftrightarrow 0.015 \text{ deg/hr/axis/gauss}^2$$

By comparison, the measured drift sensitivities at the 10-gauss level were in the order of 0.02 deg/hr/axis/gauss^2.

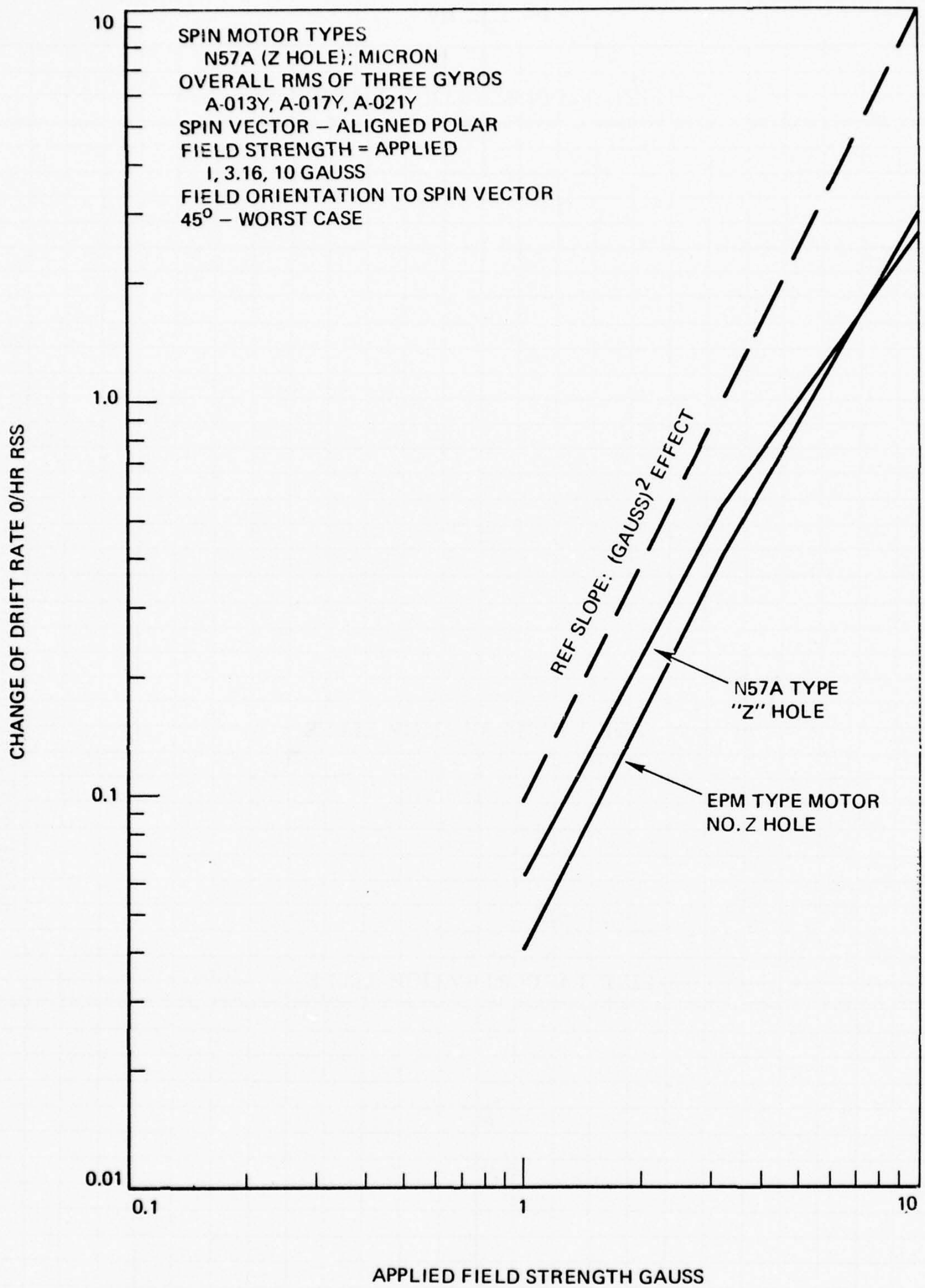


Figure F-2. Peak Radial Drift Rate Sensitivity to a Magnetic Field for Two Shield Designs

TABLE F-3. MAGNETIC FIELD SENSITIVITY SUMMARY, EFFECT ON ROTOR SPEED (Spin Vector Aligned Polar, Magnetic Field Case-Fixed Gyro A021Y)

Field Strength, Gauss	Gyro Number	Rate of Change of Rotor Speed, RPS per Minute	
		45^{o} Field Position	90^{o} Field Position
1	A013Y	-0.04	-0.05
	A017Y	-0.04	-0.05
	A021Y	-0.04	-0.05
3.16	A013Y	-0.16	-0.33
	A017Y	-0.19	-0.33
	A021Y	-0.19	-0.33
10	A013Y	-1.7	-2.8
	A0174	-1.6	-3.2
	A021Y	-1.6	-3.2

In conclusion, these tests showed no detectable angle readout sensitivity to magnetic fields and drift rate sensitivities in the order of 0.01 deg/hr/axis/gauss^2. This would yield expected rms drifts in the range of 0.0004 to 0.0050 deg/hr/axis due to natural magnetic fields. These figures tend to be consistent with the observed performance from the "rotated" N57A tests ($\sim$0.1 nmi/hr CEP rates) in which the system and its gyros were unshielded, the induced drifts appear to be within the levels of budgeted errors for EPM. However, in the case that other avionics equipment may produce magnetic fields of magnitude in excess of the natural levels, and especially in the case of high-accuracy MICRON, the use of extra shielding was considered.

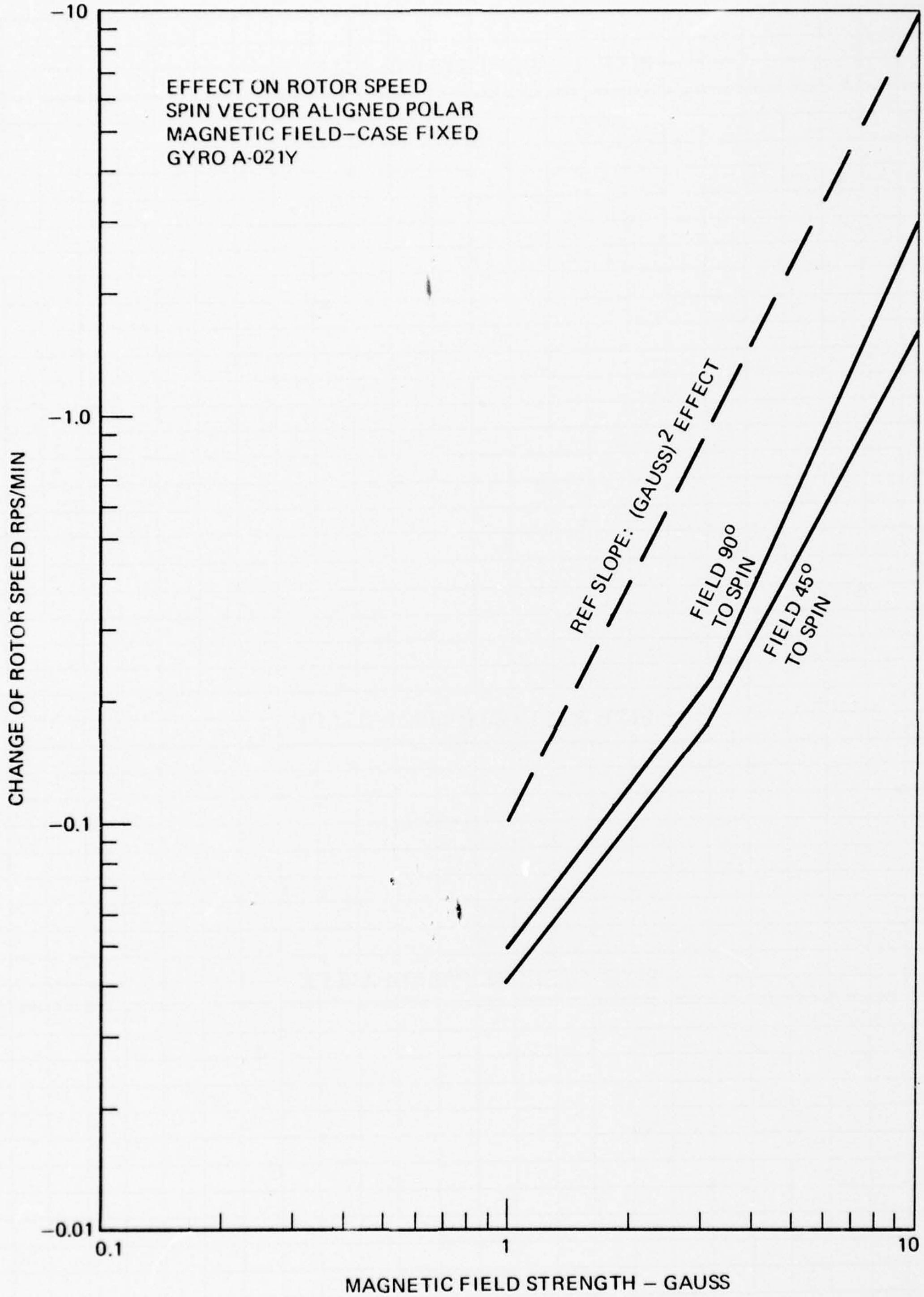


Figure F-3. Rotor Speed Sensitivity to a Magnetic Field

Under a separate IR&D task, an external magnetic shield was developed for the N57A navigation system. A series of calibrations was conducted for the purpose of determining the sensitivity of calibrated drift rates and residual drift rates to the natural magnetic field.

The effectiveness of the magnetic shield was determined by measuring (with a Hall probe) the internal magnetic field in the presence of the external natural magnetic field (~0.5 gauss). The measurements indicated a field attenuation factor of about 150:1.

Four complete sets of calibrations were performed with system shut-downs between all calibrations. The magnetic shield was installed between the second and third calibrations. In this way, the results could be compared between calibrations with no shielding change (both with and without shielding) as well as between shielded and unshielded calibrations. Each calibration included about 10 hours of data with the rotor spin axis parallel to the earth rotation axis, and about 14 hours of data with the rotor spin axis in the normal navigation directions (initially vertical and horizontal).

The resulting calibration parameters were compared in terms of the drift compensation which they would cause to be applied under the conditions of sensed acceleration and attitude (of the MESG rotor with respect to its suspension envelope) experienced during calibration. The rms compensation differences are summarized in Table F-4. These results indicate as good repeatability between shielded and unshielded calibrations as between two shielded or between two unshielded calibrations.

TABLE F-4. SUMMARY OF RMS DRIFT COMPENSATION DIFFERENCES, DEG/HR/AXIS

Cal #: / Cal #	1 (unshielded)	2 (unshielded)	3 (shielded)	4 (shielded)
1 (unshielded)	0.0 0.0	0.0048(1) 0.0053(2)	0.0040(1) 0.0043(2)	0.0049(1) 0.0054(2)
2 (unshielded)	0.0048(1) 0.0053(2)	0.0 0.0	0.0046(1) 0.0052(2)	0.0043(1) 0.0067(2)
3 (shielded)	0.0040(1) 0.0043(2)	0.0046(1) 0.0052(2)	0.0 0.0	0.0058(1) 0.0050(2)
4 (shielded)	0.0049(1) 0.0054(2)	0.0043(1) 0.0067(2)	0.0058(1) 0.0050(2)	0.0 0.0

NOTES: (1) Gyro No. 150 — (2) Gyro No. 182

As a means for evaluating the effect of shielding upon individual parameters, the "correlation coefficient" between the parameter variation and the "shielding variation" was computed for each calibration parameter for each gyro. (Two gyros in N57A were calibrated simultaneously.) The results are given in Table F-5 (for Gyro No. 150) and Table F-6 (for Gyro No. 182). There is only one parameter that has a correlation coefficient larger than 0.5 in magnitude, and having the same sign on both gyros. That is parameter number 16, which models drifts due to X-channel servo phase mismatch at rotor frequency. Its correlation coefficient with shielding has an average value of 0.6. Its rms variation on Gyro No. 150 is 0.00025; and on Gyro No. 182, 0.0016. The units of this parameter are such that these rms variations correspond to 0.0001 and 0.0008 deg/hr/axis for Gyros 150 and 182, respectively. Compared to the rss total error budget of 0.0100 deg/hr/axis, these values are insignificant. (For example, it would require about 150 independent error sources of magnitude 0.0008 deg/hr/axis to make up a rss total of 0.01 deg/hr/axis).

Since there are no significant drift rates due to natural magnetic fields which can be detected in the modeled effects, the other place to look is in the un-modeled effects; that is, in the measured drift rates that are not compensated by the calibration models. These drift rates are called "calibration residuals," and they are computed for every calibration. The rms calibration residuals for all eight calibrations are tabulated in Table F-7.

The calibration residuals for the unshielded system are, if anything, slightly larger than those for the shielded system. The difference is hardly significant, but in the case of both gyros the residual drift rates are definitely not larger in the presence of the natural magnetic field.

The main conclusion drawn from these tests is that the natural magnetic field causes no significant MESG drift rates in an unshielded nautical-mile-per-hour system. In order to evaluate system performance at higher field levels, a 13-cm diameter magnetic coil was mounted against the exterior of the N57A housing, at the point nearest the two gyros. Then, during a rotated free-inertial navigation test, the induced magnetic field level was varied discretely from 0 to 10 gauss, measured at the surface of the N57A housing at the closest point to the gyros (i.e., in the center of the coil). The distance to the center of each gyro from the center of the coil is about 10 cm. These conditions were intended to simulate the F-16 magnetic susceptibility specification.

The navigation performance, in terms of the measured velocity error, is shown in Figure F-4. Drift rate errors would appear as offsets in the mean velocity errors on this plot. There is no measurable shift during the periods of coil activation and, therefore, no detectable performance degradation due to the induced fields.

These results are not consistent with previous tests on gyro Test Station IV where drift rate sensitivities were measured. Analytical studies of the effects of system rotation, performed under a separate IR&D task, had predicted that rotation would anihilate the dominating drift sensitivity to magnetic fields and rotor drag torques. To reconcile Test Station IV and N57A test results, the N57A magnetic sensitivity tests were repeated with two important differences:

1. A coil with more turns was used, enabling higher fields to be achieved.
2. The N57A system was navigated in both the rotating and non-rotating modes during this test series. (Previous tests using an applied field were conducted with the N57A system navigating in the rotated mode only.)

TABLE F-5. SUMMARY OF CORRELATIONS BETWEEN DRIFT PARAMETER VARIATIONS AND SHIELDING FOR GYRO NO. 150

#	CALIBRATION PARAMETER VALUES CAL #1	CAL #2	CAL #3	CAL #4	MEAN VALUE	DEVIATIONS FROM THE MEAN VALUE CAL #1	CAL #2	CAL #3	CAL #4	CORR. COEF
1	.003	-.000	.002	-.000	.001	.0020	-.0014	.0010	-.0014	.16
2	-.003	-.003	-.005	-.003	-.004	.0001	.0003	-.0014	.0003	.52
3	.005	.004	.002	.003	.003	.0020	.0002	-.0013	-.0004	.81
4	.002	.014	.014	.014	.010	-.0089	.0038	.0035	.0033	-.55
5	.113	.122	.117	.114	.112	.0014	.0105	.0048	.0019	.22
6	.038	.042	.039	.041	.039	-.0002	.0035	.0007	.0024	.01
7	-.005	-.005	-.007	-.010	-.006	.0015	.0010	-.0003	-.0032	.82
8	.004	.002	.004	.002	.003	.0014	-.0006	.0005	-.0013	.28
9	.011	.009	.009	.008	.009	.0021	-.0002	.0003	-.0007	.53
10	.142	.076	.242	-.008	.109	.0337	-.0326	.1339	-.1169	-.04
11	.011	.005	.003	.004	.005	.0055	-.0004	-.0027	-.0015	.74
12	.087	-.036	.214	-.238	.007	.0802	-.0422	.2074	-.2443	.11
13	.002	.001	.002	.001	.001	.0002	-.0004	.0004	.0001	-.54
14	.021	.020	.016	.022	.019	.0017	.0008	-.0030	.0036	.19
15	.002	.002	.003	.000	.002	.0002	.0000	.0014	-.0014	.04
16	.001	.001	.002	.001	.001	.0001	-.0003	.0004	-.0000	-.53
17	-.000	-.000	-.002	-.001	-.001	.0005	.0008	-.0015	.0000	.79
18	.002	.004	.003	-.000	.002	-.0005	.0020	.0010	-.0022	.42
19	-.159	-.113	-.125	-.171	-.136	-.0231	.0231	.0116	-.0343	.23
20	-.030	-.068	-.036	-.037	-.041	.0109	-.0268	.0052	.0239	-.42
21	-.006	-.013	-.010	-.009	-.009	.0031	-.0036	-.0007	-.0003	.04
22	-.087	.246	-.146	.004	-.044	-.0430	.0899	-.1023	.0481	.34
23	.167	.241	.039	.400	.203	-.0363	.0377	-.1645	.1970	-.06
24	-.124	-.120	-.115	-.120	-.115	-.0091	-.0047	-.0001	-.0053	-.37
25	-.285	-.256	-.282	-.288	-.267	-.0186	.0103	-.0152	-.0210	.42
26	-.619	-.680	-.600	-.784	-.644	.0252	-.0366	.0443	-.1401	.27
27	.185	.011	.177	.149	.125	.0600	-.1146	.0518	.0236	-.46
28	1.104	1.218	.962	1.513	1.151	-.0475	.0666	-.1891	.3620	-.18
29	-.108	.244	-.066	.008	.019	-.1268	.2253	-.0847	-.0107	.36
30	-.897	-.989	-.799	-1.166	-.924	.0270	-.0650	.1258	-.2419	.14
31	-.094	-.350	-.176	-.169	-.189	.0956	-.1604	.0135	.0198	-.26
32	-.005	-.002	-.003	-.001	-.003	-.0022	.0006	-.0005	.0016	-.48
33	.055	.050	.061	.043	.050	.0046	-.0003	.0113	-.0073	.01
34	.028	.011	.028	.009	.018	.0097	-.0075	.0099	-.0091	.04
35	.014	.009	.015	.016	.013	.0008	-.0040	.0024	.0030	-.77

TABLE F-6. SUMMARY OF CORRELATIONS BETWEEN DRIFT PARAMETER VARIATION AND SHIELDING FOR GYRO NO. 182

#	CALIBRATION PARAMETER VALUES CAL #1	CAL #2	CAL #3	CAL #4	MEAN VALUE	DEVIATIONS FROM THE MEAN VALUE CAL #1	CAL #2	CAL #3	CAL #4	CORR. COEF
1	.003	.002	.003	.000	.002	.0006	.0000	.0011	-.0017	.32
2	.000	-.003	-.001	-.002	-.001	.0016	-.0014	.0003	-.0007	.16
3	-.002	.003	.000	-.000	.000	-.0018	.0027	-.0001	-.0008	.26
4	.002	.002	-.001	.003	.001	.0007	.0005	-.0023	.0015	.35
5	.044	.050	.042	.043	.043	.0013	.0075	-.0012	-.0004	.67
6	.019	.017	.019	.022	.018	.0006	-.0015	.0007	.0033	-.66
7	.002	.001	.005	.004	.003	-.0009	-.0016	.0024	.0006	-.90
8	-.004	-.001	-.000	-.001	-.001	-.0024	.0005	.0011	.0006	-.65
9	.001	.001	.003	.005	.003	-.0016	-.0012	.0006	.0026	-.90
10	.119	.144	.089	.259	.147	-.0272	-.0026	-.0579	.1122	-.33
11	-.003	-.001	.006	.005	.002	-.0046	-.0026	.0045	.0031	-.97
12	-.151	.525	.120	-.300	.045	-.1958	.4800	.0745	-.3512	.44
13	.000	.002	.002	.000	.001	-.0008	.0010	.0006	-.0006	.06
14	-.002	.004	-.004	-.005	-.002	.0001	.0056	-.0027	-.0032	.83
15	.001	.005	.002	.002	.003	-.0012	.0026	-.0004	-.0005	.40
16	.001	.000	.001	.005	.002	-.0004	-.0016	-.0004	.0027	-.67
17	-.001	.001	.002	-.000	.000	-.0011	.0006	.0013	-.0007	-.28
18	.003	.003	.003	.002	.003	-.0002	.0006	.0004	-.0004	.19
19	-.172	-.029	-.178	-.228	-.146	-.0265	.1168	-.0321	-.0825	.69
20	-.021	-.025	-.054	-.027	-.031	.0094	.0053	-.0231	.0033	.67
21	-.005	.000	-.003	.004	-.001	-.0043	.0012	-.0021	.0050	-.42
22	-.135	-.099	-.025	-.194	-.109	-.0266	.0094	.0842	-.0850	-.07
23	.291	-.390	.086	.461	.108	.1832	-.4981	-.0201	.3530	-.51
24	-.094	-.097	-.098	-.100	-.094	-.0009	-.0033	-.0046	-.0067	.40
25	-.268	-.255	-.249	-.251	-.246	-.0222	-.0096	-.0032	-.0059	-.45
26	-.703	-.777	-.590	-.693	-.663	-.0395	-.1143	.0735	-.0303	-.68
27	.532	.337	.476	.356	.408	.1241	-.0717	.0678	-.0521	.11
28	.926	1.110	.563	.850	.833	.0953	.2773	-.2506	.0168	.79
29	-1.196	-.817	-1.264	-.722	-.960	-.2359	.1425	-.3040	.2375	-.03
30	-.613	-.756	-.393	-.584	-.563	-.0503	-.1928	.1704	-.0211	-.75
31	.714	.508	.834	.301	.566	.1485	-.0576	.2684	-.2650	.11
32	-.005	-.007	-.008	-.006	-.006	.0011	-.0010	-.0015	.0004	.28
33	-.052	-.044	-.043	-.042	-.044	-.0087	-.0000	.0004	.0011	-.58
34	.002	.012	.001	.022	.009	-.0067	.0026	-.0076	.0132	-.28
35	.024	.022	.012	.029	.021	.0030	.0006	-.0086	.0085	.15

TABLE F-7. RMS CALIBRATION RESIDUALS

Gyro No.	RMS Calibration Residuals, Deg/Hr/Axis			
	Unshielded Calibrations		Shielded Calibrations	
	June 8 & 10	June 14 & 16	June 21 & 23	June 24 & 28
150	0.010	0.009	0.010	0.010
182	0.011	0.011	0.012	0.011

Examination of north velocity error in Figure F-5 shows no detectable performance degradation due to the induced fields where the N57A system is navigating in the rotated mode. The calculated applied maximum field strength at the gyro rotor was 11.8 gauss and the rotor was noted to slow down 3.6 rps. These results are consistent with previous N57A testing and analysis which indicates that drift rate errors due to rotor speed change and magnetic torques will be cancelled by rotation about an axis through electrode No. 1 center.

North velocity errors in Figures F-6 and F-7 indicate drift rate changes upon application of the magnetic field corresponding to sensitivities of $0.065^{\circ}/\text{hr}/\text{gauss}^2$ and $0.043^{\circ}/\text{hr}/\text{gauss}^2$ respectively. These results were obtained with the N57A system navigating in the non-rotated mode and are consistent with the $0.03^{\circ}/\text{hr}/\text{gauss}^2$ sensitivity determined from Test Station IV testing.

Magnetic sensitivity of the N57A rotated in a manner to simulate the EPM configuration (rotation axis 5° off plate center 1 - toward Z) was also tested. Analysis predicted 10 percent of the sensitivity of operation in the non-rotated mode would result. Test data indicates 15 percent to 23 percent of the sensitivity of operation in the non-rotated mode results when the N57A is rotated to simulate EPM.

Further related tests were run to verify analysis of the benefits of rotation about plate center No. 1. In the first of these tests, a larger coil was placed on the N57A and a magnetic field of magnitude sufficient to cause a rotor speed loss of 8 Hz was applied with no degradation of navigation performance. The second test resulted in no degradation of navigation performance when the polar gyro rotor was overheated approximately 10°F. Both of these tests experimentally verify the analytically predicted benefits of plate center No. 1 rotation.

In summary, the N57A magnetic sensitivity testing has verified the following:

1. In the rotated mode the N57A is relatively insensitive to magnetic fields and gyro rotor slowdown.
2. In the stationary mode the ESG demonstrates $0.03^{\circ}/\text{hr}/\text{gauss}^2$ to $0.065^{\circ}/\text{hr}/\text{gauss}^2$ magnetic sensitivity.
3. N57A2 and T/S IV magnetic sensitivity tests are in substantial agreement.
4. The EPM system sensitivity to rotor speed change and to rotor temperature change is significantly reduced from the N57A system.
5. Analytical predictions of the benefits of rotation are accurate.

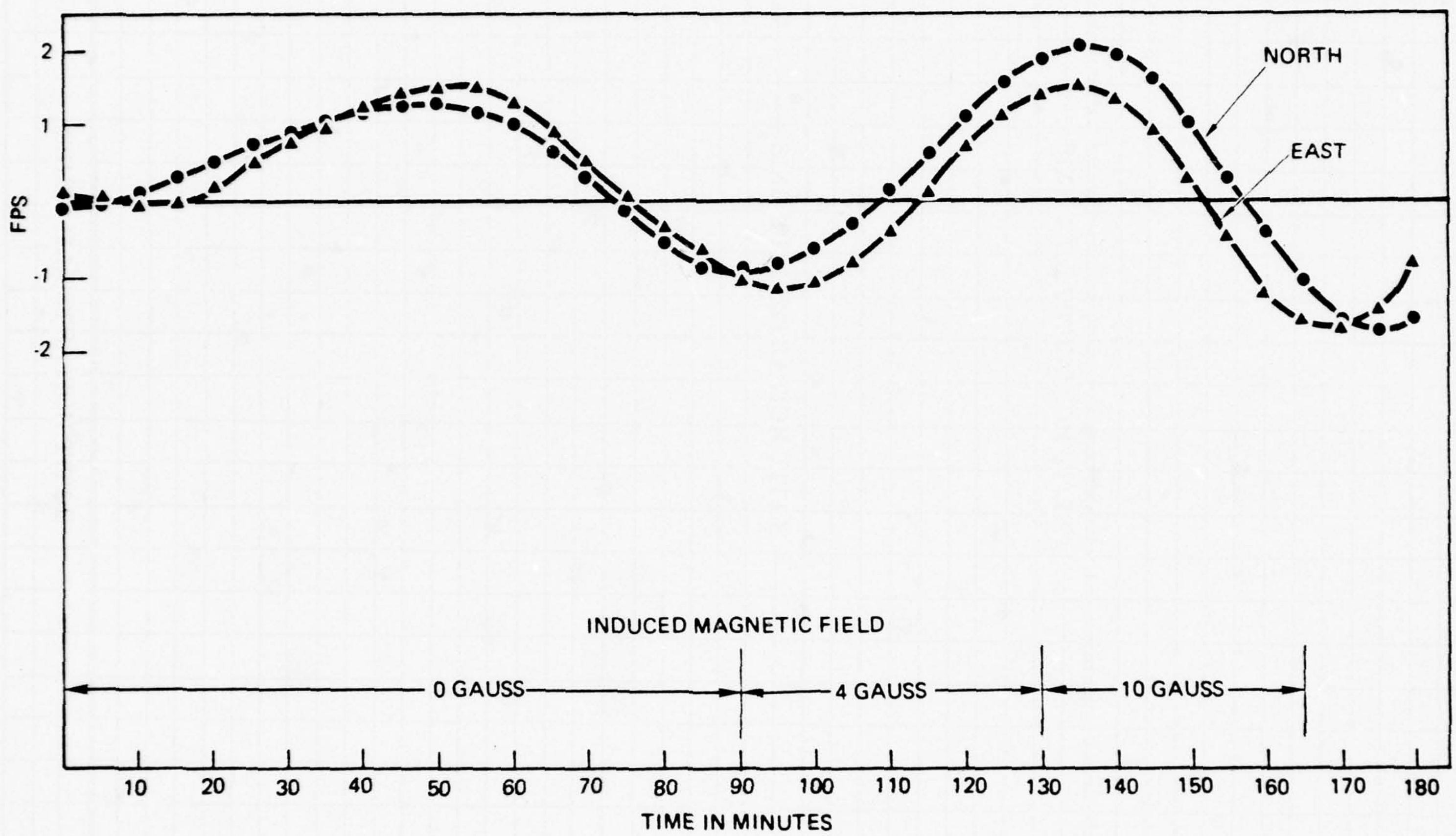
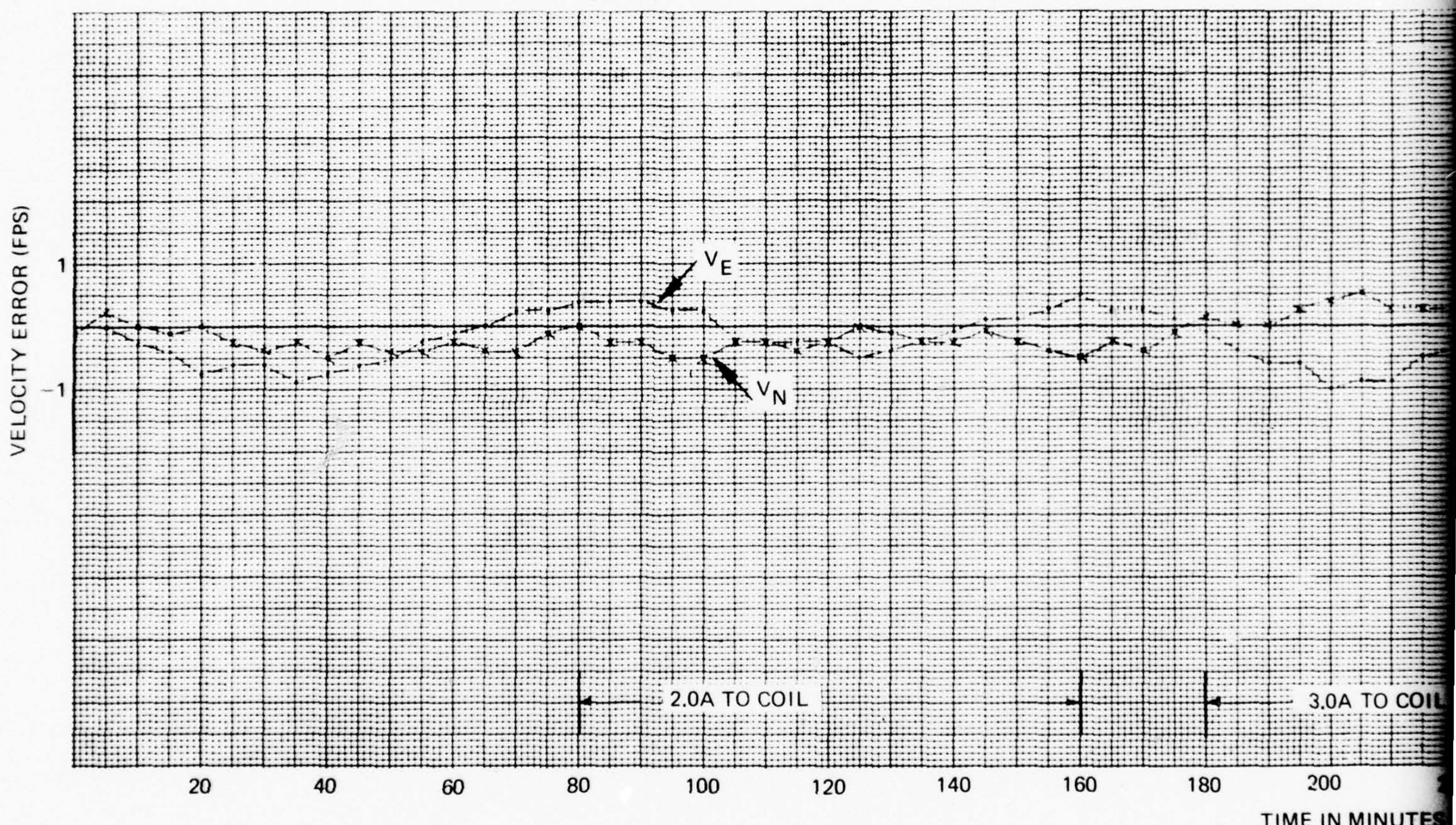


Figure F-4. Navigation Run Velocity Error

FIG F-5

Figure F-5. Magnetic Sensitivity Test - N57A2 Rotated



Reduce to 8 1/2"

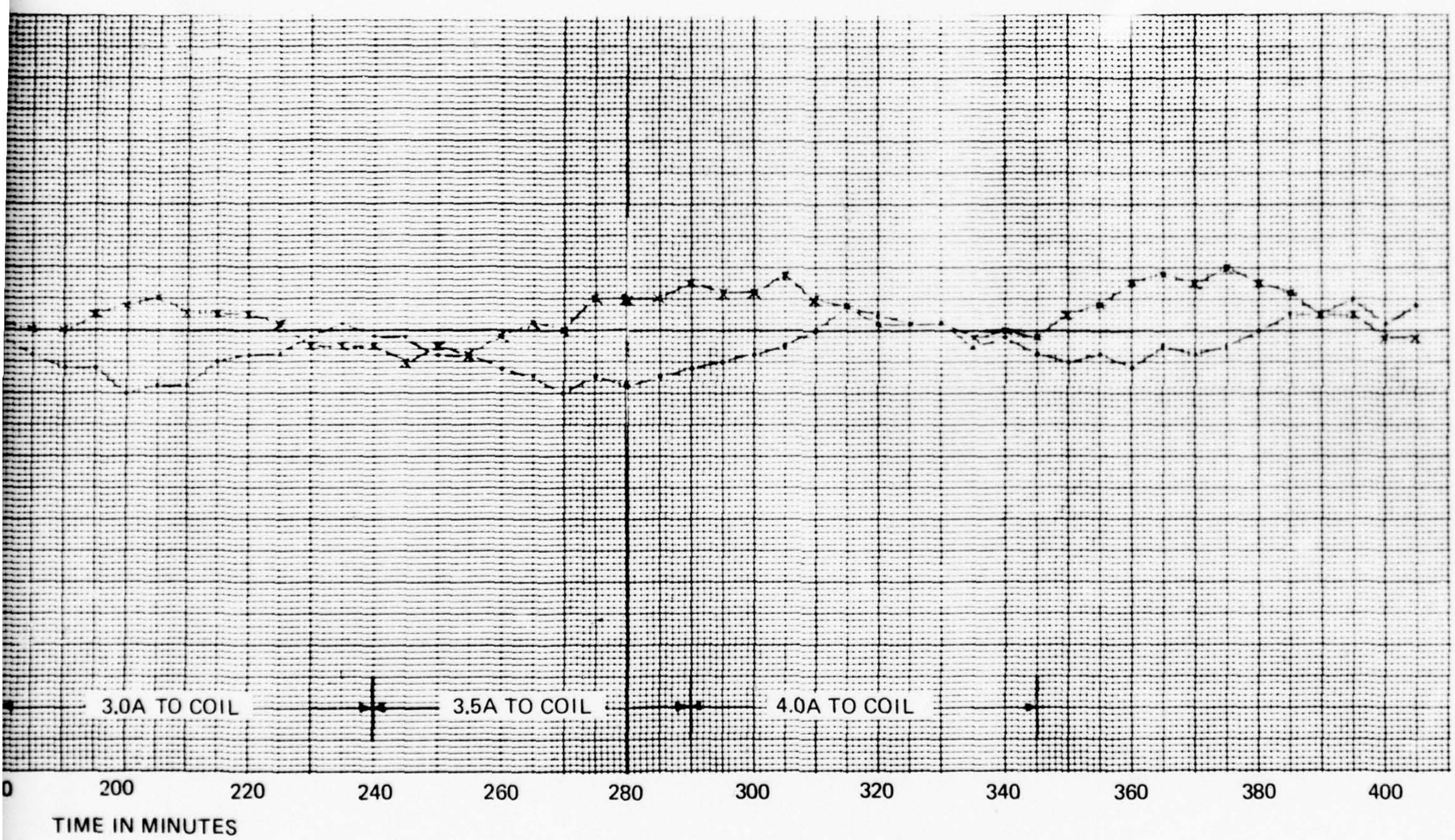

3.0A TO COIL
3.5A TO COIL
4.0A TO COIL
200
220
240
260
280
300
320
340
360
380
400
TIME IN MINUTES

FIG F-5 PG 50

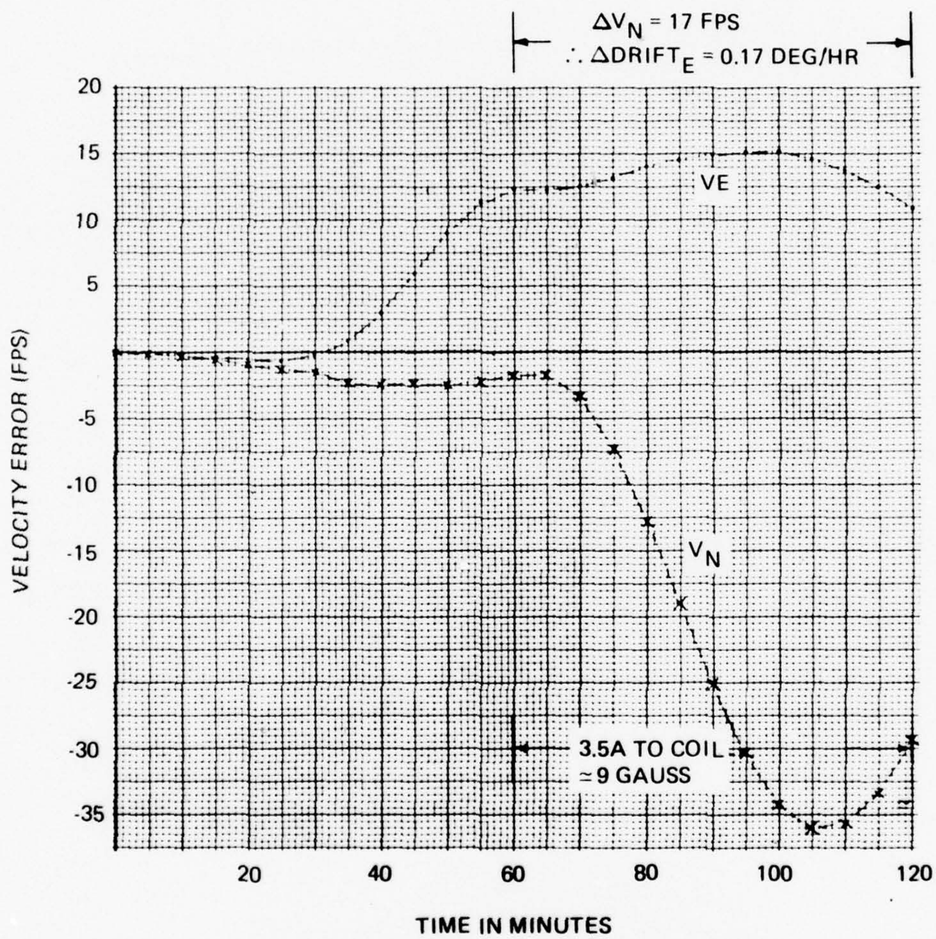


Figure F-6. Magnetic Sensitivity Test - N57A2 Stationary (180° Heading)

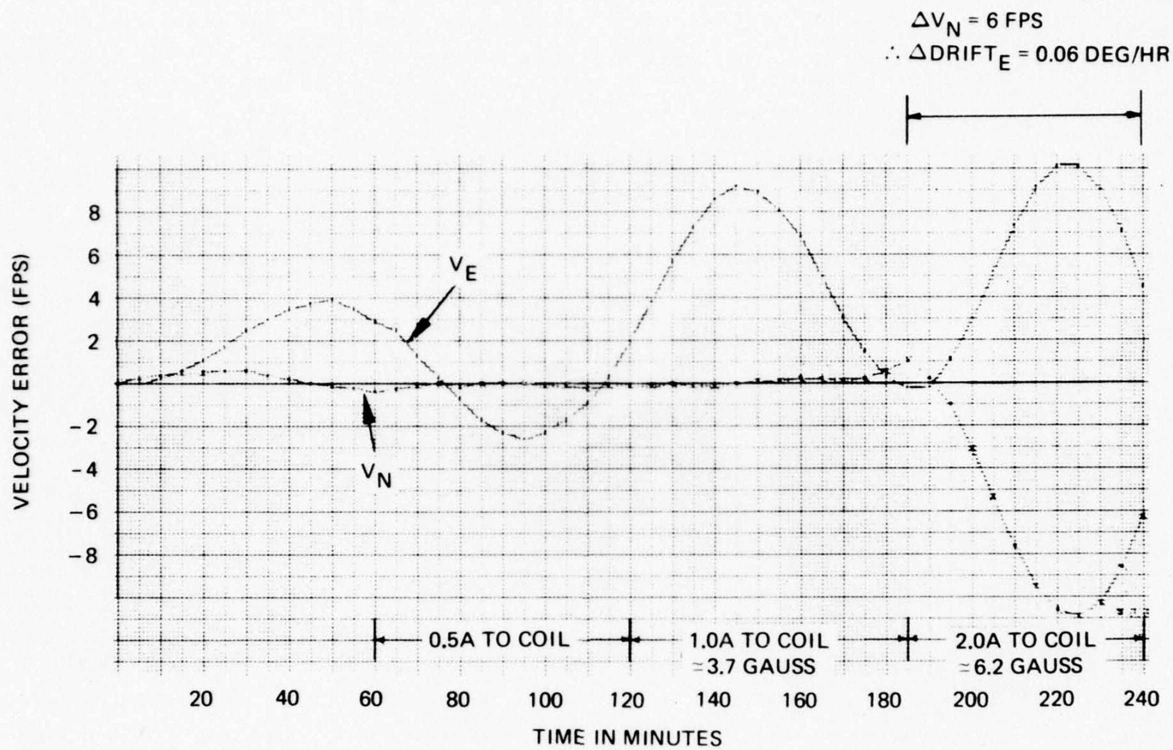
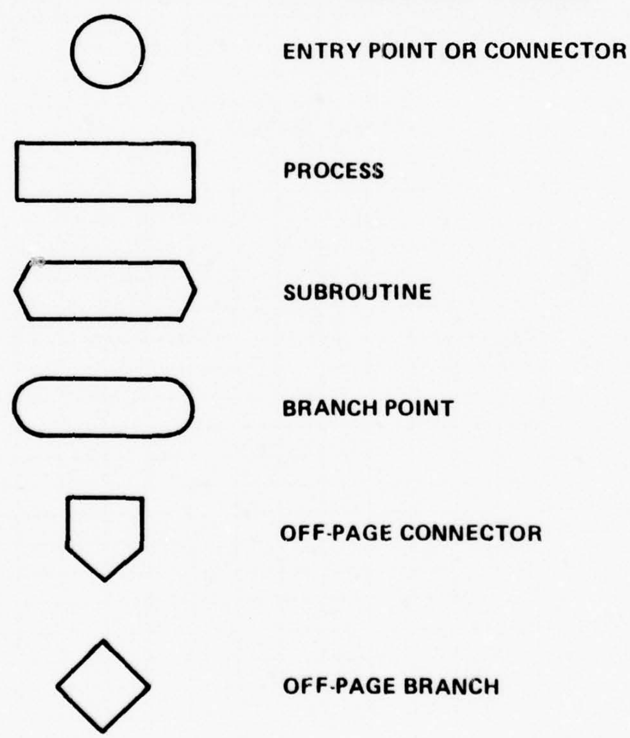


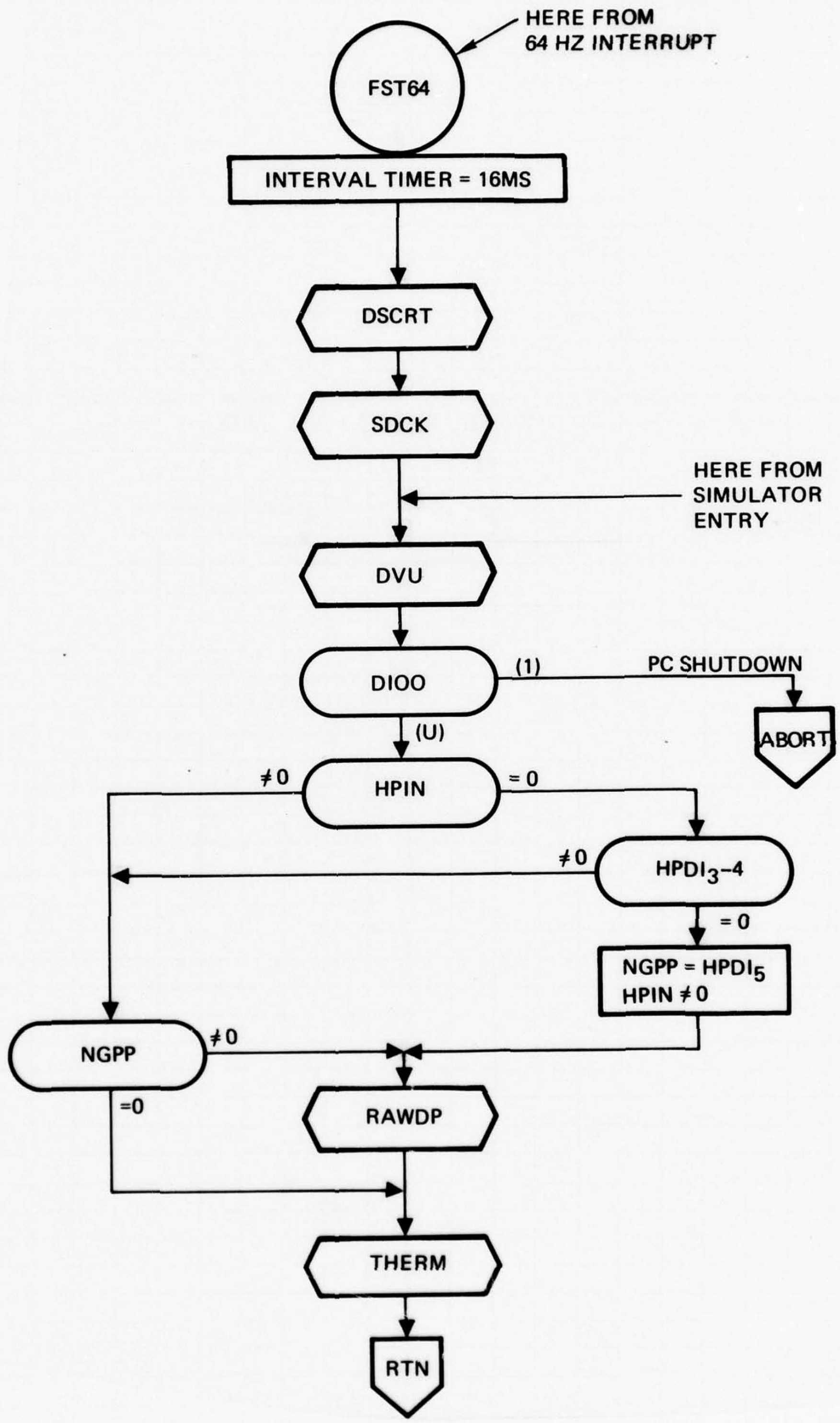
Figure F-7. Magnetic Sensitivity Test - N57A2 Stationary (0^o Heading)

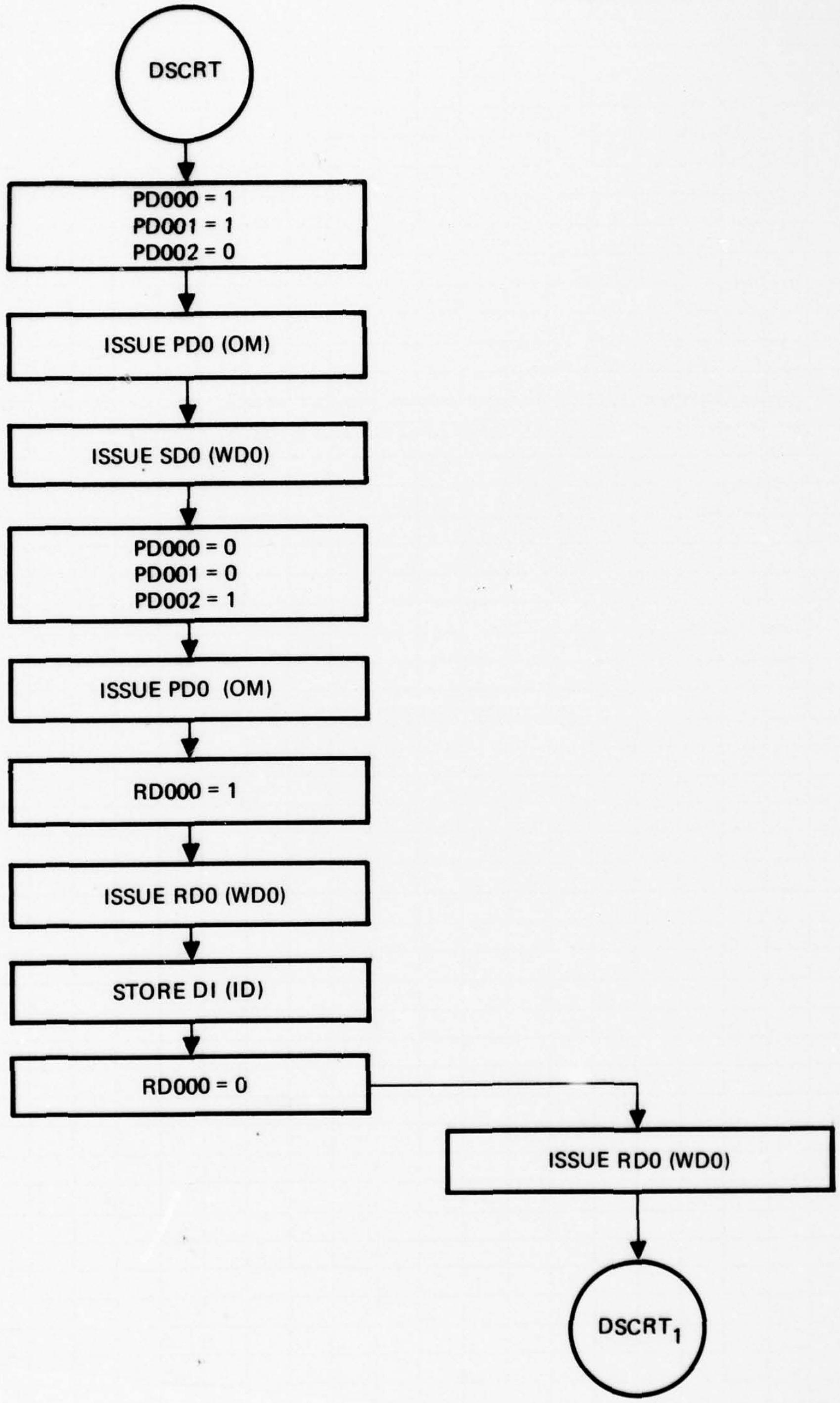
APPENDIX G

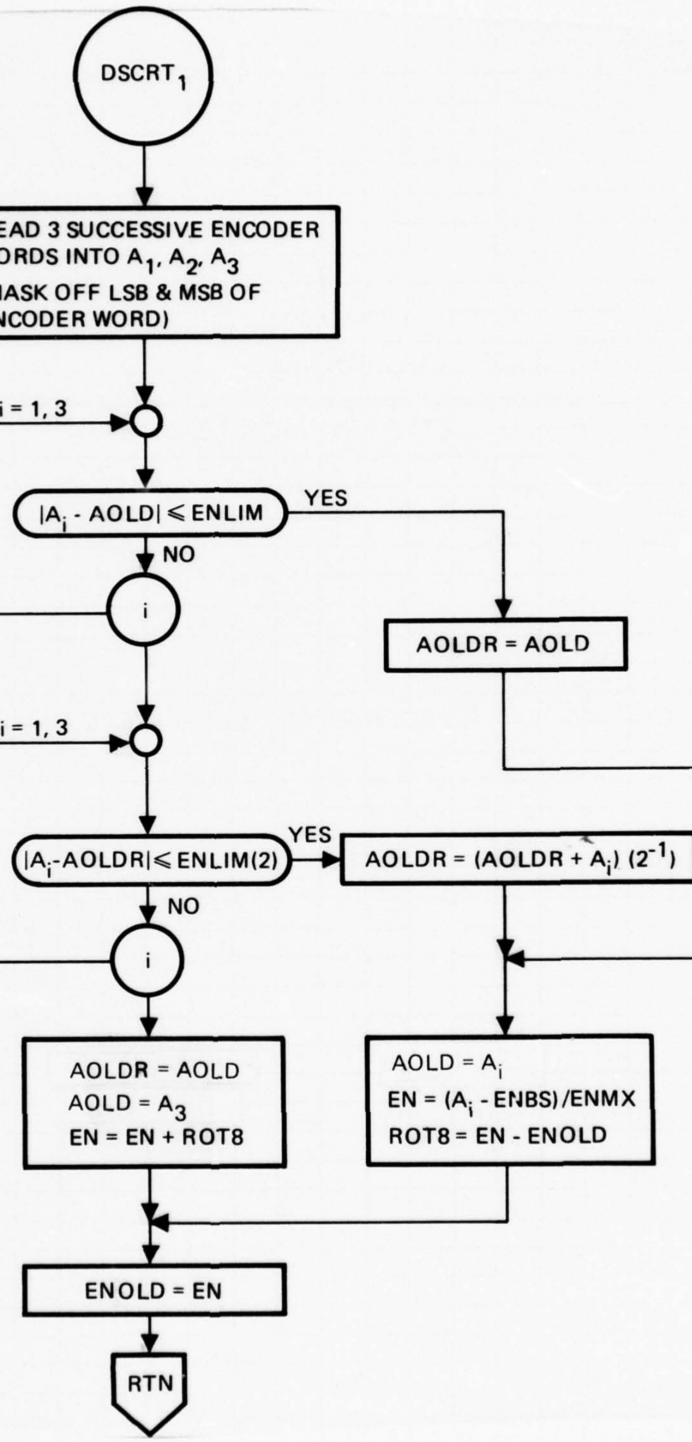
FAST CYCLE PROGRAM
DETAILED FLOW CHARTS

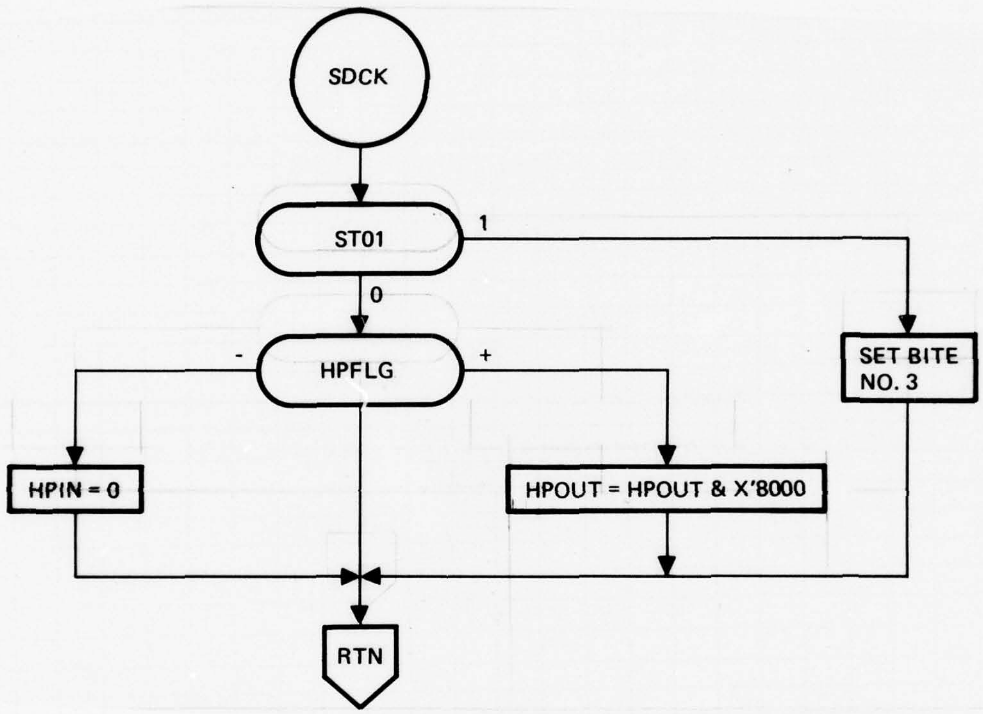
FLOW CHART SYMBOLS

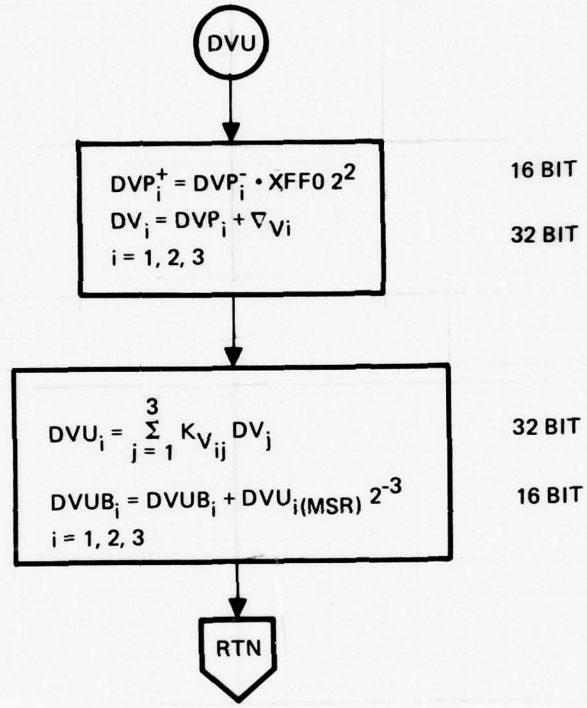


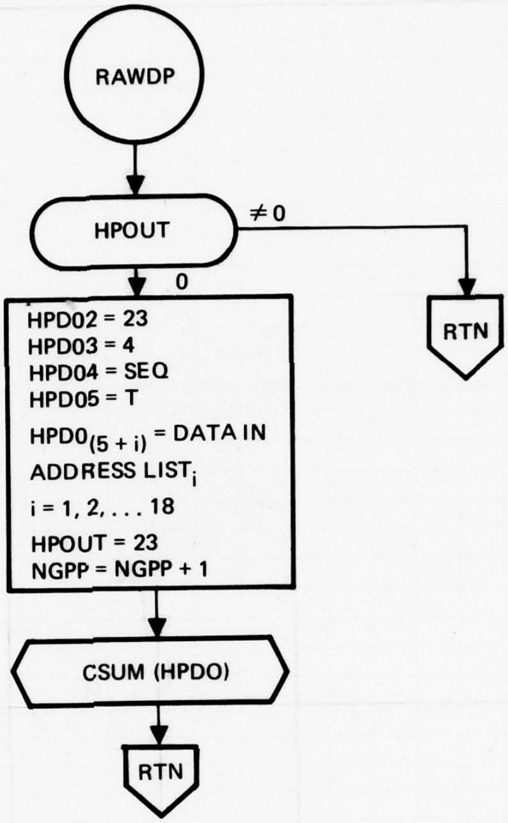

HERE FROM
64 HZ INTERRUPT
FST64
INTERVAL TIMER = 16MS
DSCRT
SDCK
HERE FROM
SIMULATOR
ENTRY
DVU
DIOO
(1)
PC SHUTDOWN
ABORT
(U)
HPIN
≠0
= 0
HPDI3–4
≠0
= 0
NGPP = HPDI5
HPIN ≠ 0
NGPP
≠0
=0
RAWDP
THERM
RTN

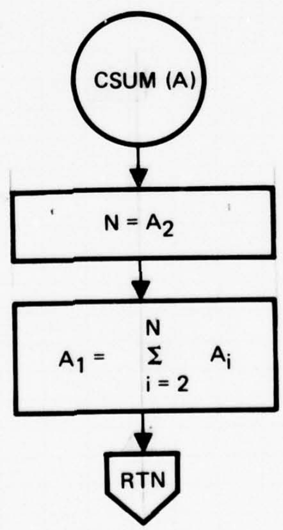

DSCRT
PD000 = 1
PD001 = 1
PD002 = 0
ISSUE PD0 (OM)
ISSUE SD0 (WD0)
PD000 = 0
PD001 = 0
PD002 = 1
ISSUE PD0 (OM)
RD000 = 1
ISSUE RD0 (WD0)
STORE DI (ID)
RD000 = 0
ISSUE RD0 (WD0)
DSCRT1

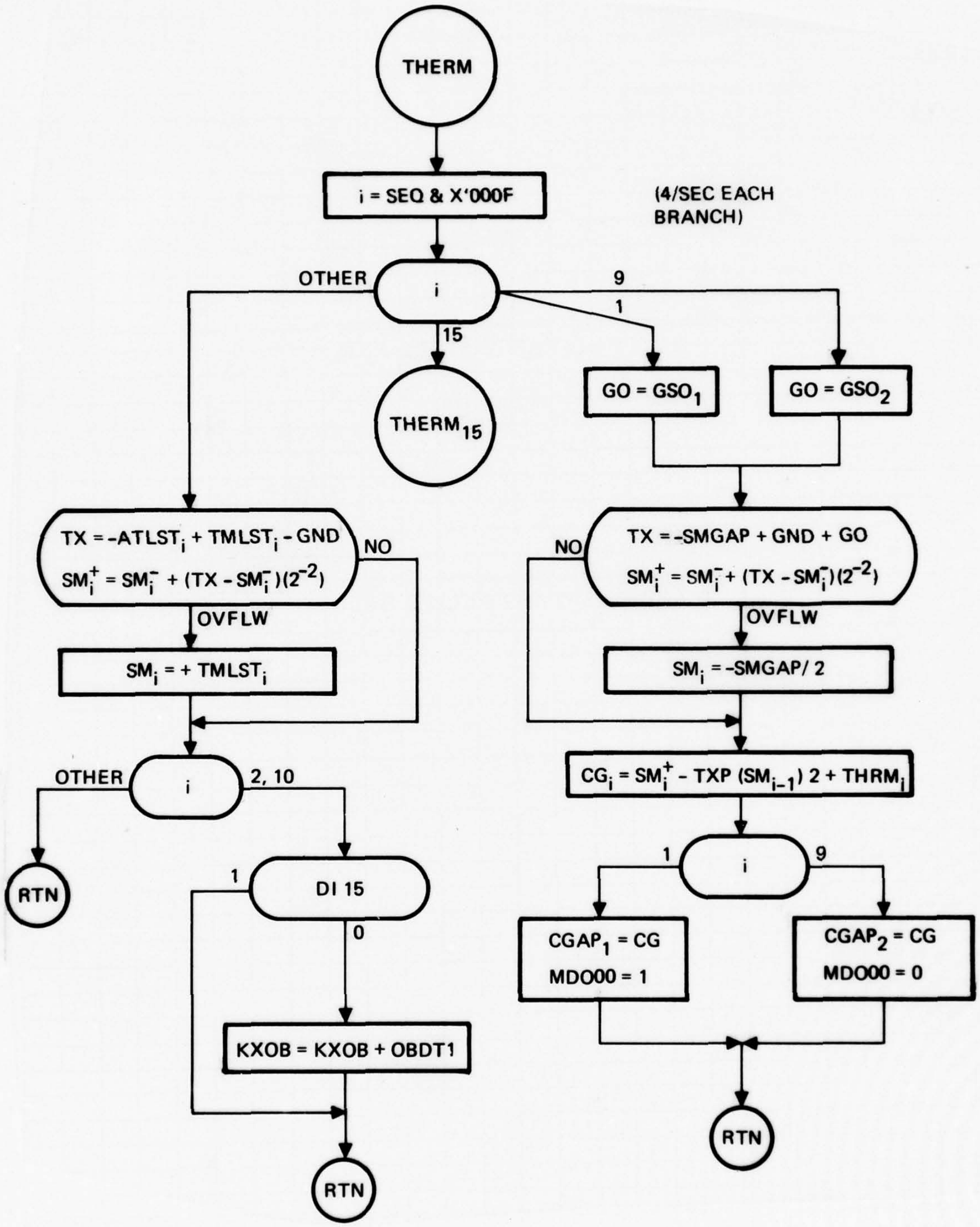

DSCRT1
READ 3 SUCCESSIVE ENCODER WORDS INTO A1, A2, A3 (MASK OFF LSB & MSB OF ENCODER WORD)
DO i = 1, 3
|Ai - AOLD| ≤ ENLIM
YES
NO
i
AOLDR = AOLD
DO i = 1, 3
|Ai-AOLDR| ≤ ENLIM(2)
YES
AOLDR = (AOLDR + Ai) (2-1)
NO
i
AOLDR = AOLD
AOLD = A3
EN = EN + ROT8
AOLD = Ai
EN = (Ai - ENBS)/ENMX
ROT8 = EN - ENOLD
ENOLD = EN
RTN

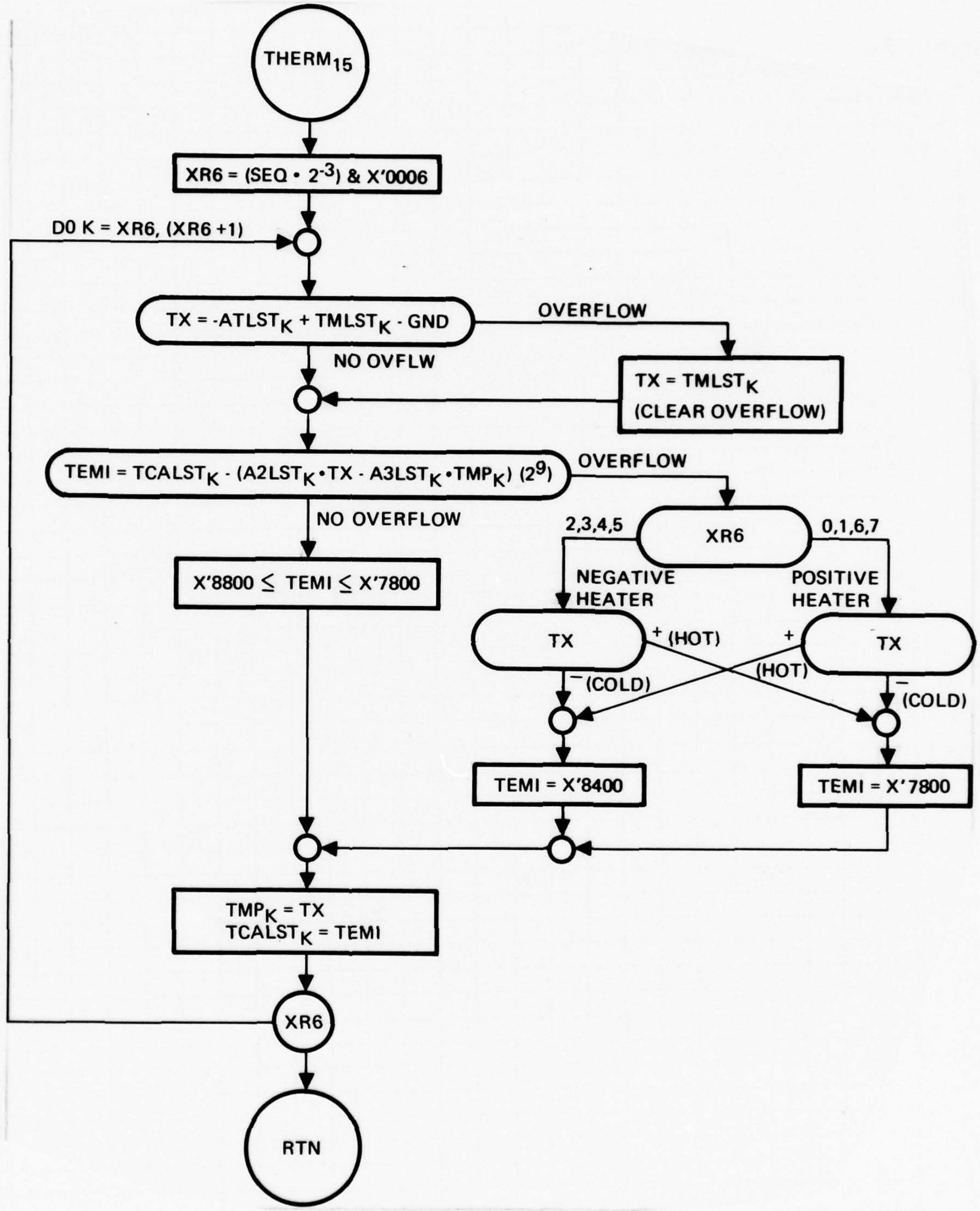

SDCK
ST01
1
0
-
HPFLG
+
SET BITE
NO. 3
HPIN = 0
HPOUT = HPOUT & X'8000
RTN

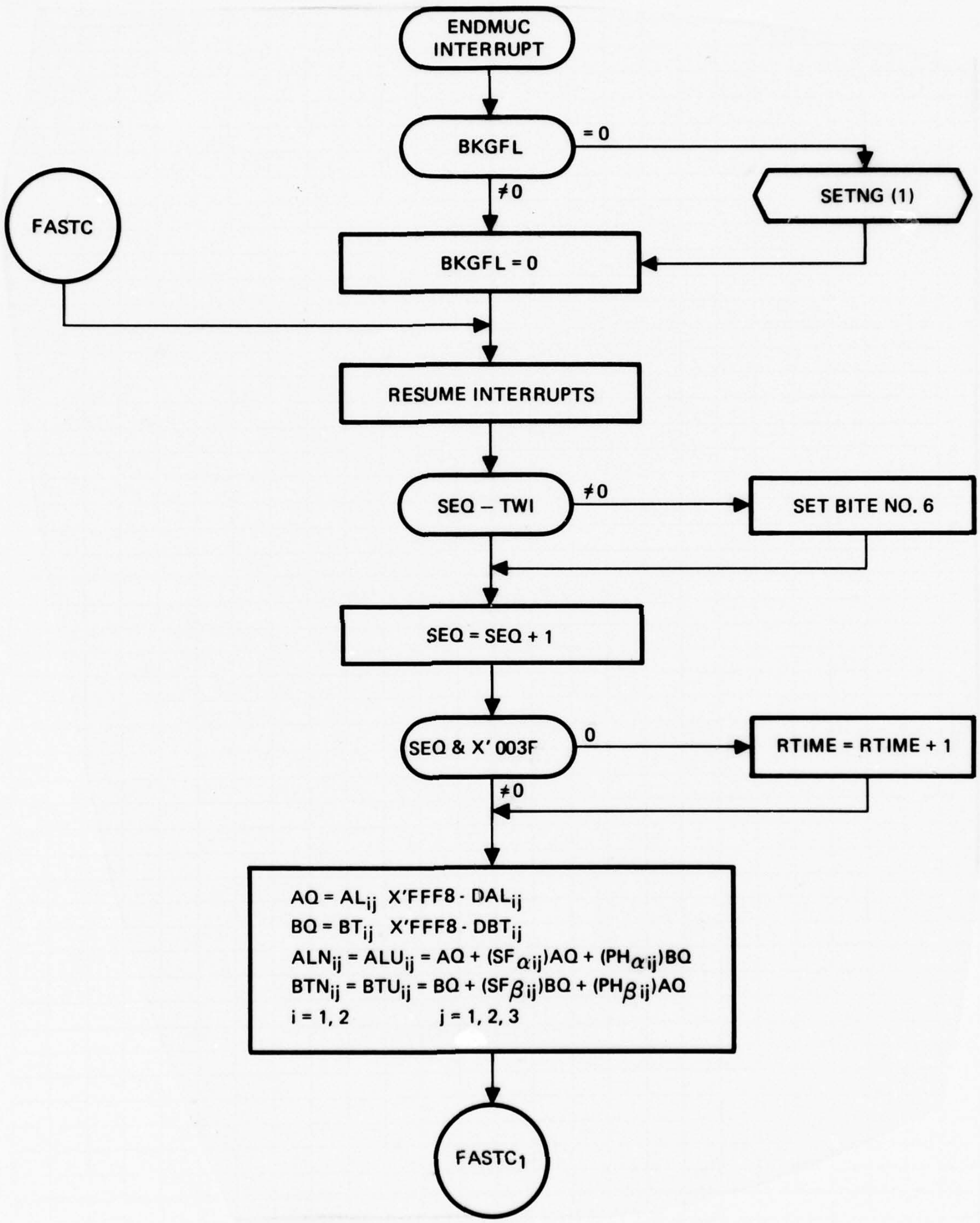

DVU
$DVP_i^+ = DVP_i^- \cdot XFF0\ 2^2$
16 BIT
$DV_i = DVP_i + \nabla_{Vi}$
32 BIT
$i = 1, 2, 3$
$DVU_i = \sum_{j=1}^{3} K_{V_{ij}} DV_j$
32 BIT
$DVUB_i = DVUB_i + DVU_{i(MSR)}\ 2^{-3}$
16 BIT
$i = 1, 2, 3$
RTN


RAWDP
HPOUT
≠ 0
0
RTN
HPD02 = 23
HPD03 = 4
HPD04 = SEQ
HPD05 = T
HPD0(5 + i) = DATA IN ADDRESS LIST i
i = 1, 2, . . . 18
HPOUT = 23
NGPP = NGPP + 1
CSUM (HPDO)
RTN

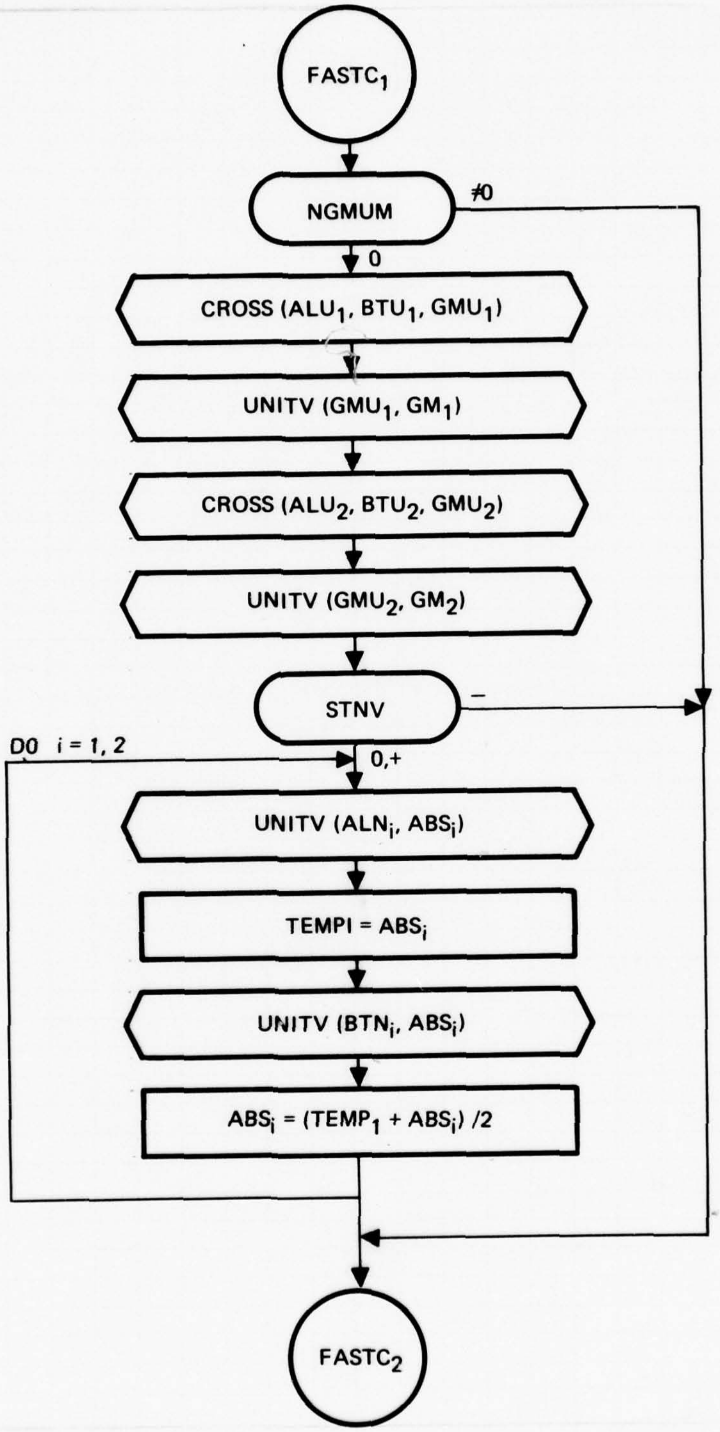

CSUM (A)
N = A2
A1 = Σ (i = 2 to N) Ai
RTN

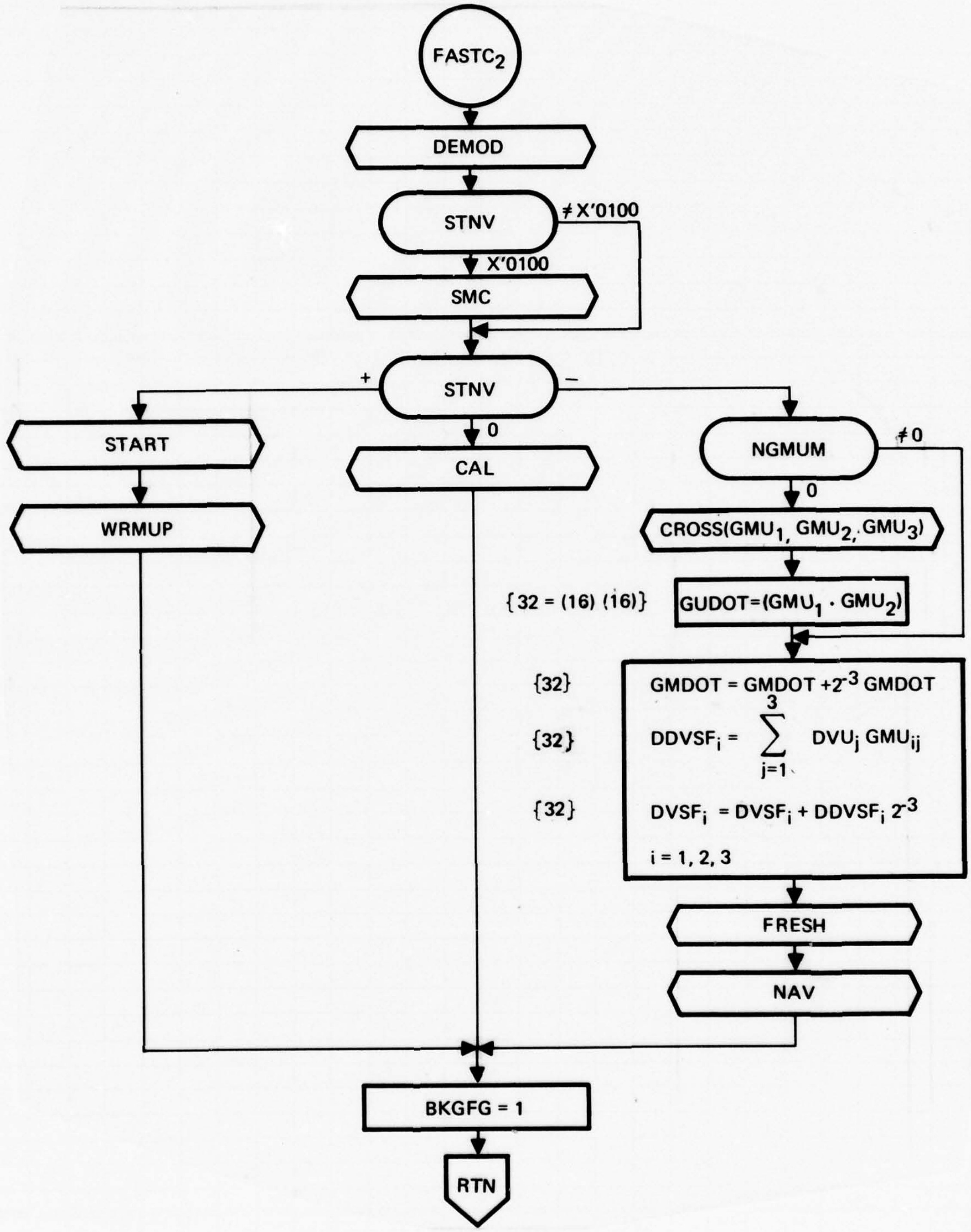

THERM
i = SEQ & X'000F
(4/SEC EACH BRANCH)
OTHER
i
9
1
15
THERM15
GO = GSO1
GO = GSO2
TX = -ATLSTi + TMLSTi - GND
SMi+ = SMi- + (TX - SMi-)(2-2)
NO
OVFLW
SMi = + TMLSTi
TX = -SMGAP + GND + GO
SMi+ = SMi- + (TX - SMi-)(2-2)
NO
OVFLW
SMi = -SMGAP/ 2
OTHER
i
2, 10
RTN
DI 15
1
0
KXOB = KXOB + OBDT1
RTN
CGi = SMi+ - TXP (SMi-1) 2 + THRMi
1
i
9
CGAP1 = CG
MDO00 = 1
CGAP2 = CG
MDO00 = 0
RTN

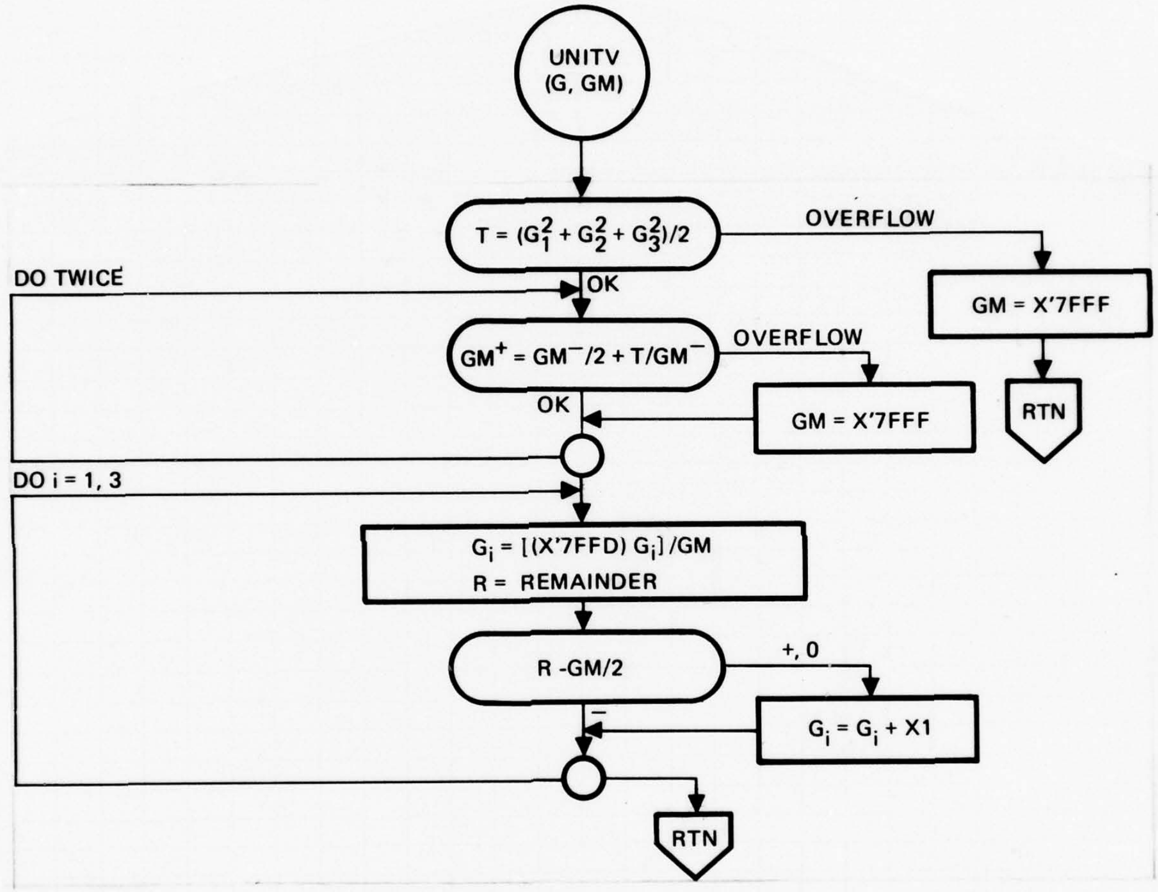

THERM15
XR6 = (SEQ • 2-3) & X'0006
DO K = XR6, (XR6 +1)
TX = -ATLSTK + TMLSTK - GND
OVERFLOW
NO OVFLW
TX = TMLSTK
(CLEAR OVERFLOW)
TEMI = TCALSTK - (A2LSTK•TX - A3LSTK•TMPK) (29)
OVERFLOW
NO OVERFLOW
XR6
2,3,4,5
0,1,6,7
X'8800 ≤ TEMI ≤ X'7800
NEGATIVE HEATER
POSITIVE HEATER
TX
TX
+ (HOT)
+
(HOT)
− (COLD)
−
(COLD)
TEMI = X'8400
TEMI = X'7800
TMPK = TX
TCALSTK = TEMI
XR6
RTN

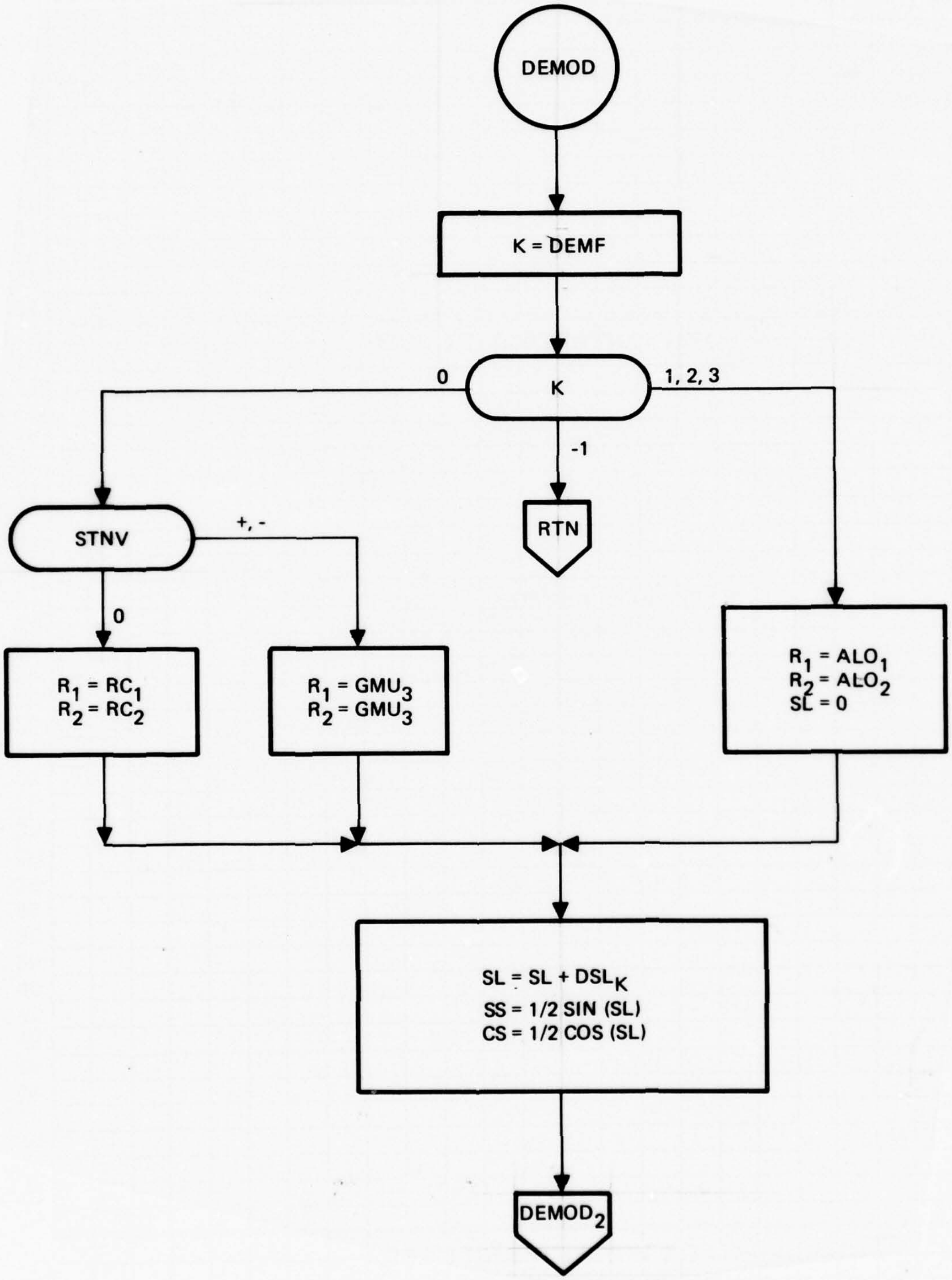


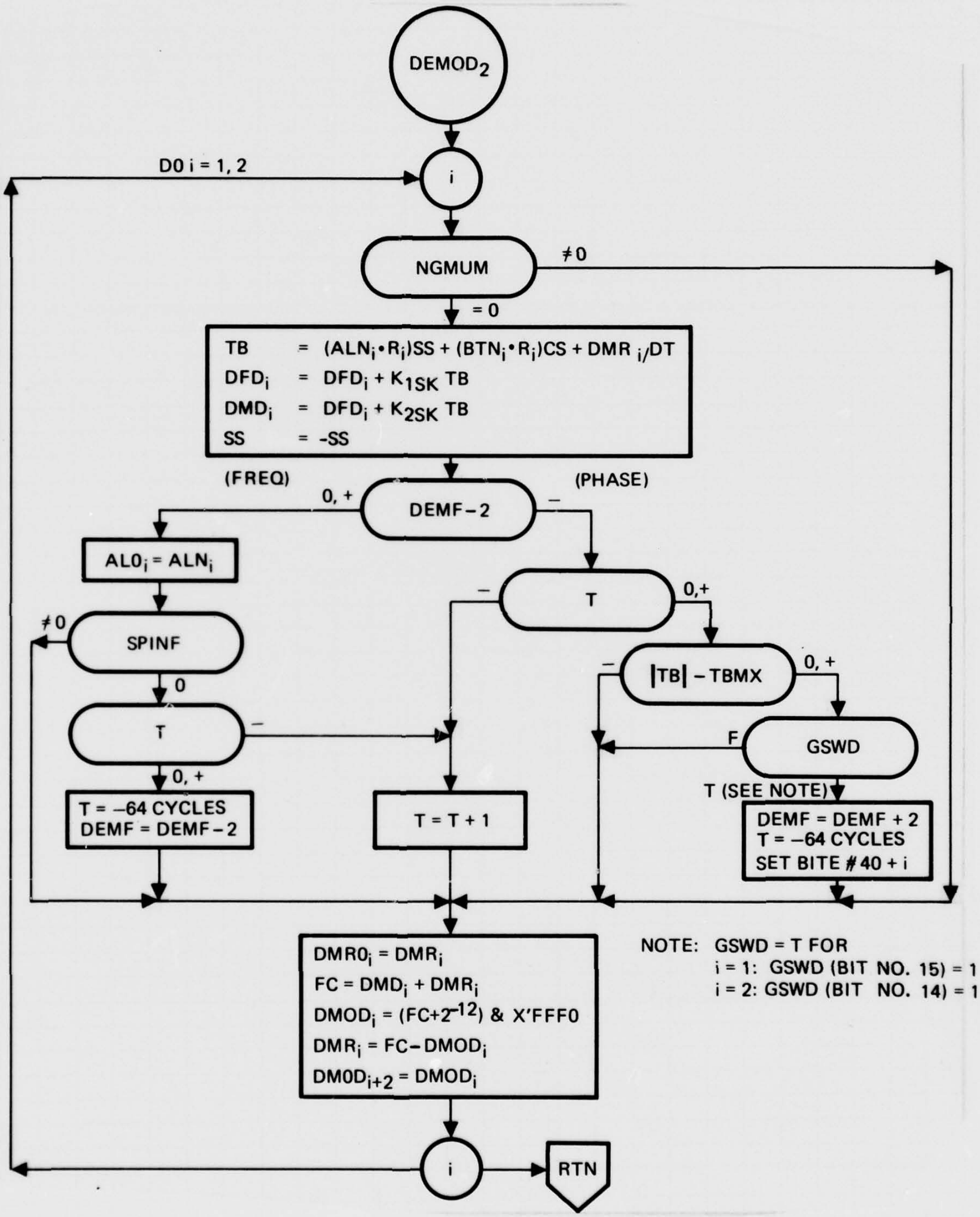
ENDMUC INTERRUPT
BKGFL
= 0
≠0
SETNG (1)
FASTC
BKGFL = 0
RESUME INTERRUPTS
SEQ – TWI
≠0
SET BITE NO. 6
SEQ = SEQ + 1
SEQ & X' 003F
0
RTIME = RTIME + 1
≠0
AQ = AL_ij X'FFF8 - DAL_ij
BQ = BT_ij X'FFF8 - DBT_ij
ALN_ij = ALU_ij = AQ + (SF_αij)AQ + (PH_αij)BQ
BTN_ij = BTU_ij = BQ + (SF_βij)BQ + (PH_βij)AQ
i = 1, 2 j = 1, 2, 3
FASTC_1

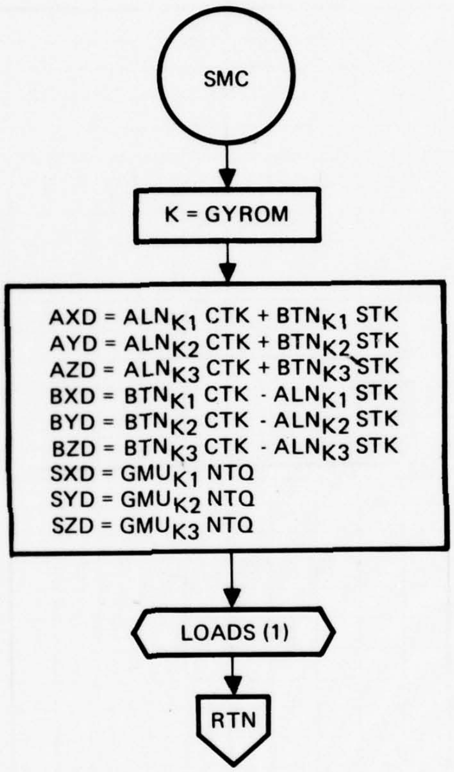

FASTC1
NGMUM
≠0
0
CROSS (ALU1, BTU1, GMU1)
UNITV (GMU1, GM1)
CROSS (ALU2, BTU2, GMU2)
UNITV (GMU2, GM2)
STNV
–
DO i = 1, 2
0,+
UNITV (ALNi, ABSi)
TEMPI = ABSi
UNITV (BTNi, ABSi)
ABSi = (TEMP1 + ABSi) /2
FASTC2

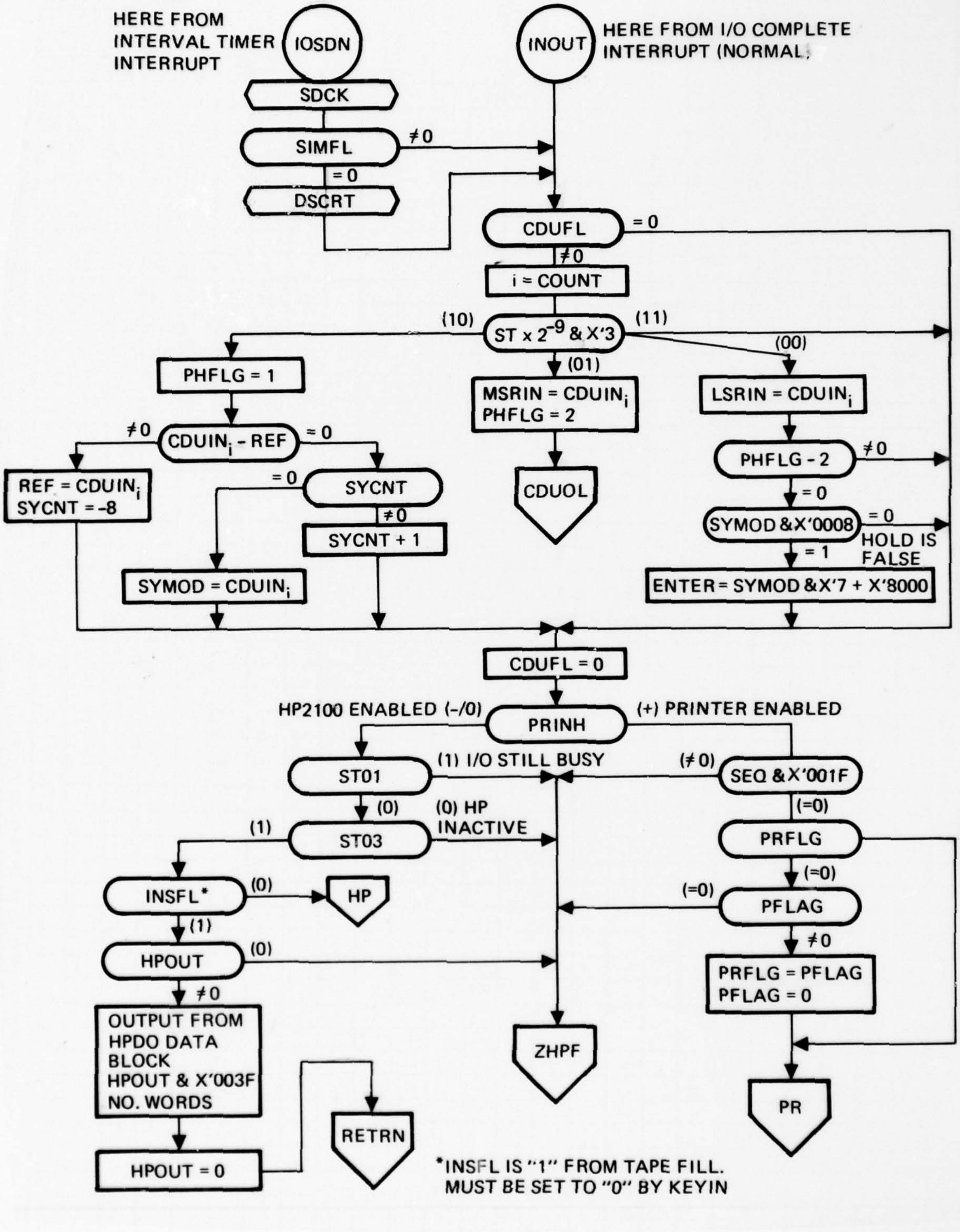

FASTC2
DEMOD
STNV
≠ X'0100
X'0100
SMC
STNV
+
−
0
START
WRMUP
CAL
NGMUM
≠ 0
0
CROSS(GMU1, GMU2, GMU3)
{32 = (16) (16)}
GUDOT = (GMU1 · GMU2)
{32}
GMDOT = GMDOT + 2-3 GMDOT
{32}
DDVSFi = Σ j=1 3 DVUj GMUij
{32}
DVSFi = DVSFi + DDVSFi 2-3
i = 1, 2, 3
FRESH
NAV
BKGFG = 1
RTN

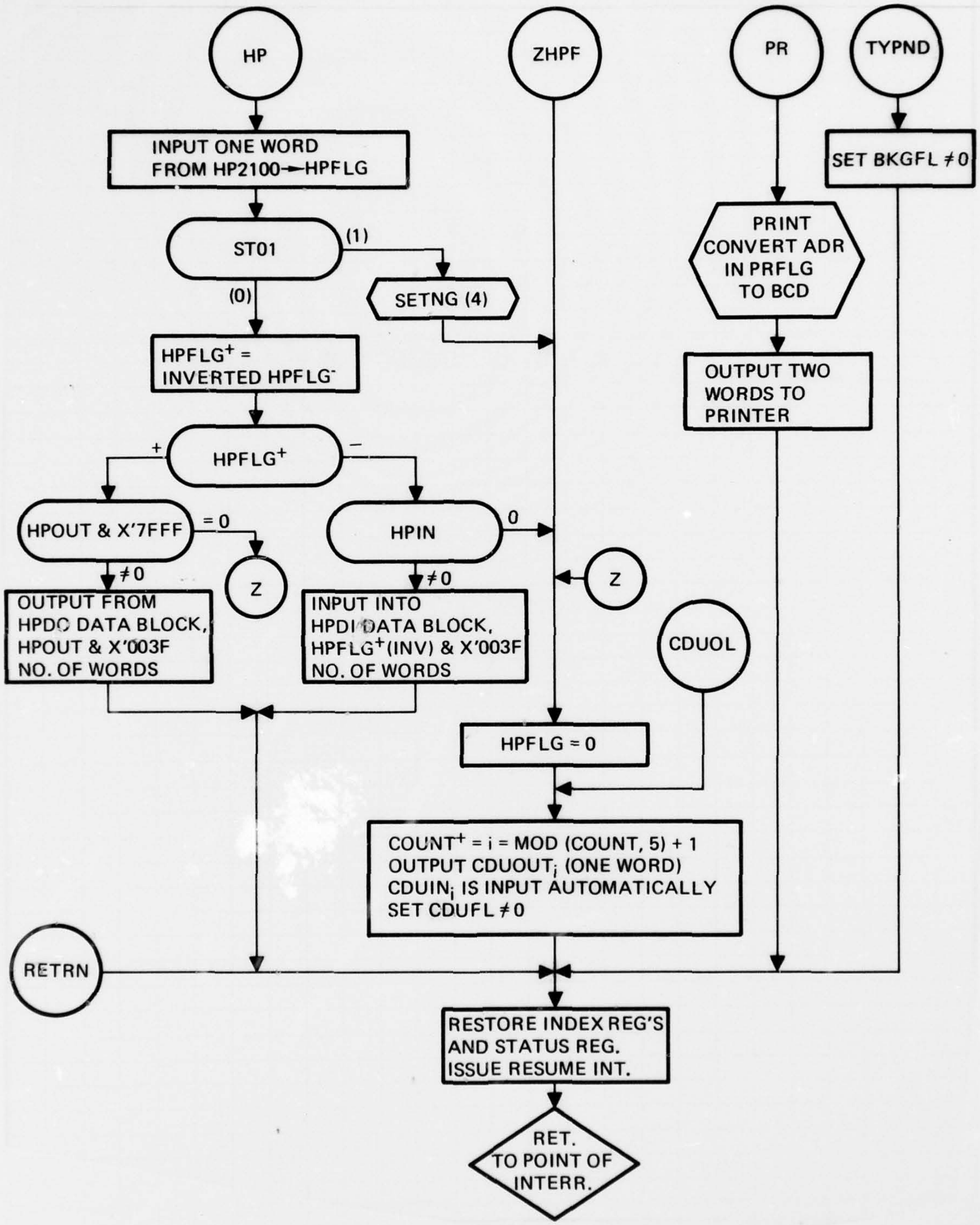

UNITV
(G, GM)
T = (G$_1^2$ + G$_2^2$ + G$_3^2$)/2
OVERFLOW
GM = X'7FFF
RTN
DO TWICE
OK
GM$^+$ = GM$^-$/2 + T/GM$^-$
OVERFLOW
OK
GM = X'7FFF
DO i = 1, 3
G$_i$ = [(X'7FFD) G$_i$] /GM
R = REMAINDER
R -GM/2
+, 0
–
G$_i$ = G$_i$ + X1
RTN


DEMOD
K = DEMF
K
0
1, 2, 3
-1
RTN
STNV
+, -
0
R1 = RC1
R2 = RC2
R1 = GMU3
R2 = GMU3
R1 = ALO1
R2 = ALO2
SL = 0
SL = SL + DSLK
SS = 1/2 SIN (SL)
CS = 1/2 COS (SL)
DEMOD2


DEMOD2
DO i = 1, 2
i
NGMUM
≠0
= 0
TB = (ALNi•Ri)SS + (BTNi•Ri)CS + DMR i/DT
DFDi = DFDi + K1SK TB
DMDi = DFDi + K2SK TB
SS = -SS
(FREQ)
(PHASE)
0, +
DEMF − 2
−
AL0i = ALNi
T
0,+
≠0
SPINF
|TB| − TBMX
0, +
0
T
F
GSWD
0, +
T (SEE NOTE)
T = −64 CYCLES
DEMF = DEMF − 2
T = T + 1
DEMF = DEMF + 2
T = −64 CYCLES
SET BITE # 40 + i
DMR0i = DMRi
FC = DMDi + DMRi
DMODi = (FC+2-12) & X'FFF0
DMRi = FC−DMODi
DM0Di+2 = DMODi
NOTE: GSWD = T FOR
i = 1: GSWD (BIT NO. 15) = 1
i = 2: GSWD (BIT NO. 14) = 1
i
RTN


SMC
K = GYROM
AXD = ALN$_{K1}$ CTK + BTN$_{K1}$ STK
AYD = ALN$_{K2}$ CTK + BTN$_{K2}$ STK
AZD = ALN$_{K3}$ CTK + BTN$_{K3}$ STK
BXD = BTN$_{K1}$ CTK - ALN$_{K1}$ STK
BYD = BTN$_{K2}$ CTK - ALN$_{K2}$ STK
BZD = BTN$_{K3}$ CTK - ALN$_{K3}$ STK
SXD = GMU$_{K1}$ NTQ
SYD = GMU$_{K2}$ NTQ
SZD = GMU$_{K3}$ NTQ
LOADS (1)
RTN


HERE FROM INTERVAL TIMER INTERRUPT
IOSDN
SDCK
SIMFL
≠0
= 0
DSCRT
INOUT
HERE FROM I/O COMPLETE INTERRUPT (NORMAL)
CDUFL
= 0
≠0
i = COUNT
ST x 2-9 & X'3
(10)
(11)
(00)
(01)
PHFLG = 1
MSRIN = CDUINi
PHFLG = 2
LSRIN = CDUINi
CDUINi - REF
≠0
= 0
REF = CDUINi
SYCNT = -8
SYCNT
SYCNT + 1
SYMOD = CDUINi
CDUOL
PHFLG - 2
SYMOD & X'0008
HOLD IS FALSE
= 1
ENTER = SYMOD & X'7 + X'8000
CDUFL = 0
HP2100 ENABLED (-/0)
PRINH
(+) PRINTER ENABLED
ST01
(1) I/O STILL BUSY
(≠0)
SEQ & X'001F
(=0)
(0)
ST03
(0) HP INACTIVE
(1)
PRFLG
INSFL*
HP
PFLAG
HPOUT
PRFLG = PFLAG
PFLAG = 0
OUTPUT FROM HPDO DATA BLOCK HPOUT & X'003F NO. WORDS
ZHPF
PR
RETRN
HPOUT = 0
*INSFL IS "1" FROM TAPE FILL. MUST BE SET TO "0" BY KEYIN



HP
ZHPF
PR
TYPND
INPUT ONE WORD FROM HP2100→HPFLG
SET BKGFL ≠ 0
ST01
(1)
(0)
SETNG (4)
PRINT CONVERT ADR IN PRFLG TO BCD
HPFLG⁺ = INVERTED HPFLG⁻
OUTPUT TWO WORDS TO PRINTER
+
HPFLG⁺
–
HPOUT & X'7FFF
= 0
HPIN
0
Z
≠ 0
≠ 0
Z
OUTPUT FROM HPDO DATA BLOCK, HPOUT & X'003F NO. OF WORDS
INPUT INTO HPDI DATA BLOCK, HPFLG⁺(INV) & X'003F NO. OF WORDS
CDUOL
HPFLG = 0
COUNT⁺ = i = MOD (COUNT, 5) + 1
OUTPUT CDUOUTᵢ (ONE WORD)
CDUINᵢ IS INPUT AUTOMATICALLY
SET CDUFL ≠ 0
RETRN
RESTORE INDEX REG'S AND STATUS REG. ISSUE RESUME INT.
RET. TO POINT OF INTERR.

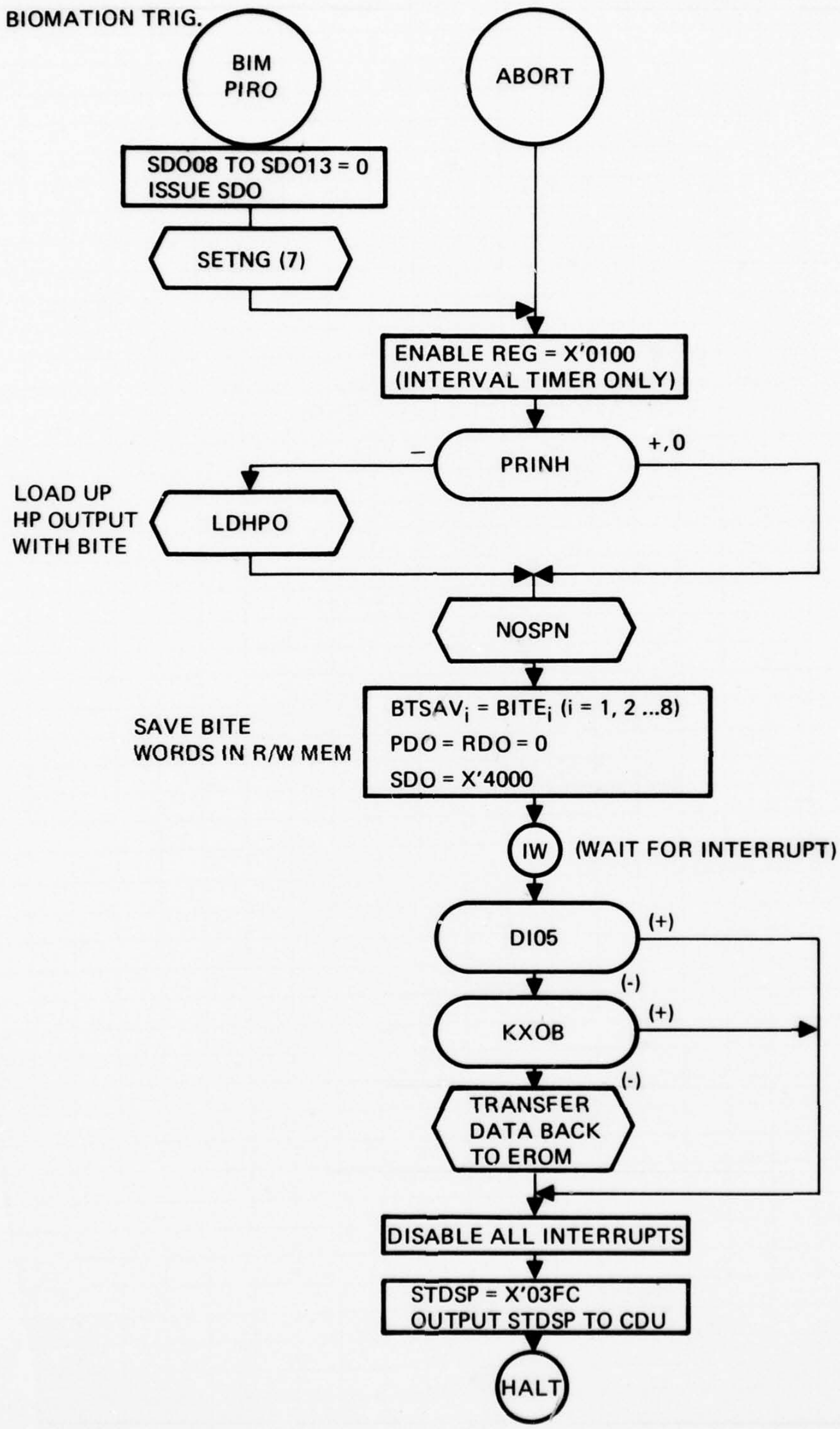

BIOMATION TRIG.
BIM
PIRO
ABORT
SDO08 TO SDO13 = 0
ISSUE SDO
SETNG (7)
ENABLE REG = X'0100
(INTERVAL TIMER ONLY)
–
PRINH
+,0
LOAD UP
HP OUTPUT
WITH BITE
LDHPO
NOSPN
SAVE BITE
WORDS IN R/W MEM
BTSAV$_i$ = BITE$_i$ (i = 1, 2 ...8)
PDO = RDO = 0
SDO = X'4000
IW
(WAIT FOR INTERRUPT)
DI05
(+)
(-)
KXOB
(+)
(-)
TRANSFER
DATA BACK
TO EROM
DISABLE ALL INTERRUPTS
STDSP = X'03FC
OUTPUT STDSP TO CDU
HALT

TABLE G-1. FAST CYCLE VARIABLES

Symbol	Index		Definition	Max Value	Word Length (Bits)
	i	j			
BKGFG	–	–	Set True When in Background, False When in Fast or Slow Cycles	–	16
ISWD	–	–	Instrument Status Word = 3 Both Gyros Operating = 2 Gyro 2 Operating = 1 Gyro 1 Operating	–	16
GSWD	–	–	Demod Routine Gyro Status, Perform BITE Test: 3 – Both Gyros 2 – Gyro 2 1 – Gyro 1	–	16
STNV	–	–	Slow Cycle Mode START = + CALIBRATE = 0 NAVIGATE = -	–	16
DEMF	–	–	Demod Routine Mode = 0 5 Hz Slip, Phase Lock = 1 0 Slip, Phase Lock = 2 5 Hz Slip, Freq Lock = 3 0 Slip, Freq Lock = -1 No Control	–	16
NGMUM	–	–	MUM Data Not Good $\neq 0$	–	16
SPINF	–	–	Hold Demod Routine in Freq Lock Mode $\neq 0$, Perform Normal Mode Sequencing = 0	–	16

TABLE G-1. (Cont)

Symbol	Index		Definition	Max Value	Word Length (Bits)
	i	j			
SIMFL	–	–	Simulator Flag 0 – No Simulator (Normal) + – Start, Rotor Desuspended - – Nav, Rotor Suspended, Spun (Load SIMFL = 0)	–	16
SYMOD	–	–	System Mode from C/D Panel Switch (Load SYMOD = X'15)	–	16
SYMDO	–	–	Old Value of C/D Panel Mode Switch	–	16
COUNT	–	–	Modulo 5 Counter to Sequence C/D Panel Output	–	16
PFLAG	–	–	Print Flag Set by Program. Address of List of Data Addresses (0 – No Print) (Load PFLAG = 0)	–	16
PRFLG	–	–	Buffered PFLAG (Load PRFLG = 0)	–	16
HPOUT	–	–	Length of HP Output Data Buffer (HPDO) HPOUT = 0 For No Output	–	16
HPIN	–	–	HP Input Data Buffer (HPDI) Contains Data If HPIN = 0	–	16
HPFLG	–	–	I/O Control Word from HP2100 HPFLG = + Micron Output Request HPFLG = - Micron Input Request	–	16
ENTER	–	–	Keyboard Input Code (SYMOD) (0 – No Input) (Load ENTER = 0)	–	16
LSRIN, MSRIN	–	–	Least and Most Significant Keyboard Input	–	16

TABLE G-1. (Cont)

Symbol	Index i	Index j	Definition	Max Value	Word Length (Bits)
ALU_{ij} BTU_{ij}	Gyro (1, 2)	Axis (1, 2, 3)	DC Offset and 3-Space Scale Factor, Phase Compensated α, β	1.	16
GMU_{ij}	Gyro (1, 2, 3)	Axis (1, 2, 3)	ALU x BTU and Normalized $GMU_3 = GMU_1 \times GMU_2$	1.	16
DAL_{ij} DBT_{ij}	Gyro (1, 2)	Axis (1, 2, 3)	α, β DC Offsets (Initialize From Cal Param)	1.	32
GM_i	Gyro (1, 2)	–	Magnitude of (ALU x BTU)	1.	16
DVU_i	Axis (1, 2, 3)	–	Compensated EMA Data – MICRON Frame	2^4fps	32
$DVUB_i$	Axis (1, 2, 3)	–	Summed DVU_i	2^7 fps	16
$DVSF_i$	Axis (1, 2, 3)	–	Compensated EMA Data – Spin Frame	2^7 fps	32
SEQ	–	–	Sequence Counter (64/Sec)	2^{15} Cycles	16
DFD_i	Gyro (1, 2)	–	Demod Control Freq Estimate	1302.08 Hz	32
S_L	–	–	Demod Routine Reference Phase Angle	π Rad	16
SS, CS	–	–	Sin and Cos of S_L	1.	16
RC_i	Gyro (1, 2)	–	Demod Routine Phase Lock Reference Vector – Cal Mode	1.	16
DMR_i	Gyro (1, 2)	–	Demod Control Residual Phase/1/64 Second	1302.08 Hz	16
$DMRO_i$	Gyro (1, 2)	–	DMR_i Lagged 1/64 Sec	1302.08 Hz	16
T	–	–	Demod Routine Mode Sequence Timer (64/Sec)	2^{15} Cycles	16

TABLE G-1. (Cont)

Symbol	Index		Definition	Max Value	Word Length (Bits)
	i	j			
ALN_{ij} BTN_{ij}	Gyro (1, 2)	Axis (1, 2, 3)	Normalized ALU and BTU	1.	16
ABS_i	Gyro (1, 2)	–	Length of (|ALU| + |BTU|)/2	1.	16
RTIME	–	–	1 sec Clock	2^{15} sec	16
SMCS1	–	–	Smoothed Gyro No. 1 Case Temp	521°F	16
SMCS2	–	–	Smoothed Gyro No. 2 Case Temp	521°F	16
SMCA1	–	–	Smoothed Charge Amp No. 1 Temp	312.5°F	16
SMCA2	–	–	Smoothed Charge Amp No. 2 Temp	312.5°F	16
SMEMA	–	–	Smoothed EMA Block Temp	312.5°F	16
SMS1	–	–	Smoothed SEU No. 1 Temp	312.5°F	16
SMS2	–	–	Smoothed SEU No. 2 Temp	312.5°F	16
SMS3	–	–	Smoothed SEU No. 3 Temp	312.5°F	16
SMMX1	–	–	Smoothed MUX No. 1 Temp	312.5°F	16
SMMX2	–	–	Smoothed MUX No. 2 Temp	312.5°F	16
SMAIR	–	–	Smoothed Air Temp	312.5°F	16
SMBAT	–	–	Smoothed Battery Temp	312.5°F	16
SMTCM	–	–	Smoothed Converter Module Temp	312.5°F	16
$SGAP_i$	1, 2	–	Smoothed Gyro Gap	167.9 μin	16
$CGAP_i$	1, 2	–	Compensated Rotor Temp	167.9 μin	16

TABLE G-1. (Concluded)

Symbol	Index		Definition	Max Value	Word Length (Bits)
	i	j			
CT_i, ST_i	Gyro 1, 2	–	Cos, Sin Polhode Damping Torque Angle	1	16
ALO_i	Gyro 1, 2	–	Old Value of ALN_i	1.	16
$CDUI_i$	1, 2, 3, 4, 5	–	CDU Input Data Buffer	–	16
EN	–	–	IAU Rotation Encoder Position	180^0	16
CDUFL			= 1 If CDU Data Were Output Previous Fast Cycle = 0 Otherwise	–	16
KXOB	–	–	Integral of Battery Current	130 amp-sec	16
$TMPK_i$	1, 2, . . ., 8	–	Previous Value of Temp Control Loop Error Signals	1.	16
NGPP	–	–	Raw Data Transmission Counter (Negative)	2^{15}	16
AOLD	–	–	Old Value of EN (Unscaled)	363^0	16
AOLDR	–	–	2 Cycles Old Value of EN	363^0	16
ROT8	–	–	Change in EN Over 1 Cycle	180^0	16

TABLE G-2. FAST CYCLE CONSTANTS

Symbol	Definition	Value	Max Value	Scaled Value
DSL_0	Demod Slip Frequency (5.08625 Hz)	0.025297 Rad	π	0.158045
DSL_1	(Mode Determined by DEMF) (0 Hz)	0	π	0
DSL_2	(5.08625 Hz)	0.025297 Rad	π	0.158045
DSL_3	(0 Hz)	0	π	0
K_{1S0}	Demod Control Gain, Slip-Phase (Freq)	–(0.02376) (64)/Sec	π (1302.08)/Sec	–0.0003717
K_{2S0}	(τ = 1/8 Sec, ζ = 0.7) (Phase)	–(0.2073) (64)/Sec	π (1302.08)/Sec	–0.003244
K_{1S1}	Demod Control Gain, 0 Slip-Phase (Freq)	–(0.1078 (64)/Sec	"	–0.001678
K_{2S1}	(τ = 1/32 Sec, ζ = 0.7) (Phase)	–(0.4741) (64)/Sec	"	–0.007416
K_{1S2}	Demod Control Gain, Slip-Freq (Freq)	–8/Sec	"	–0.00199
K_{2S2}	(τ = 1/8 Sec) (Phase)	0	"	0
K_{1S3}	Demod Control Gain 0 Slip-Freq (Freq)	–16/Sec	"	–0.00390
K_{2S3}	(τ = 1/16 Sec) (Phase)	0	"	0
DT	Demod Control – Residual Freq Scaling	64/Sec	π (1302.08)/Sec	0.0625829
TBMX	*Demod Control BITE Threshold*	*Sin 60°*	2	0.433
TXP	Case Expansion Coefficient	0.467μ in./°F	$\left(\frac{167.9\,\mu \text{ in.}}{521\,^{\circ}\text{F}}\right)^2$	0.724559
ENMX	Encoder Max Value	319/[(320) (2)]	1	0.4984375
ENBS	Encoder Bias	1/2 – ENMX	1	0.0015625
ENLIM	Encoder Wild Point Limit (0.13°)	6	2^{14}	0.000366

TABLE G-2. (Cont)

Symbol	Definition	Value	Max Value	Scaled Value
$A2LST_1$	Temp Controller Gains	3.9331	4	0.98328
$A2LST_2$		3.9331	4	0.98328
$A2LST_3$		-0.9678	4	-0.24195
$A2LST_4$		-0.9678	4	-0.24195
$A2LST_5$		-0.8585	4	-0.24163
$A2LST_6$		-0.6463	4	-0.16158
$A2LST_7$		0.6463	4	0.16158
$A2LST_8$		0.6463	4	0.16158
$A3LST_1$	Temp Controller Gains	3.6796	4	0.919844
$A3LST_2$		3.6796	4	0.919844
$A3LST_3$		-0.9283	4	-0.23208
$A3LST_4$		-0.9283	4	-0.23208
$A3LST_5$		-0.8415	4	-0.21038
$A3LST_6$		-0.6264	4	-0.1566
$A3LST_7$		0.6264	4	0.1566
$A3LST_8$		0.6464	4	0.1566

TABLE G-3. THERM MEMORY MAP

SEQ$_i$	SM$_i$				Input TMLST		Set Point ATLST						
0	SMCS1	=	SMCS1$^-$	+	[TMG1	-	ATMG1	-	GND	-	SMCS1$^-$]	(2^{-2})	
1	SGAP1	=	SGAP1$^-$	+	[-SMGAP	+	GS01	+	GND	-	SGAP1$^-$]	(2^{-2})	& CGAP1$^+$ = SGAP1$^+$ -(TXP) (SMCS1$^+$)
2	SMCA1	=	SMCA1$^-$	+	[TMCA1	-	ATMC1	-	GND	-	SMCA1$^-$]	(2^{-2})	& DI15 Battery Check
3	SMCA2	=	SMCA2$^-$	+	[TMCA2	-	ATMC2	-	GND	-	SMCA2$^-$]	(2^{-2})	
4	SMEMA	=	SMEMA$^-$	+	[TMEMA	-	ATME	-	GND	-	SMEMA$^-$]	(2^{-2})	
5	SMS1	=	SMS1$^-$	+	[TMS1	-	ATMS1	-	GND	-	SMS1$^-$]	(2^{-2})	
6	SMS2	=	SMS2$^-$	+	[TMS2	-	ATMS2	-	GND	-	SMS2$^-$]	(2^{-2})	
7	SMS3	=	SMS3$^-$	+	[TMS3	-	ATMS3	-	GND	-	SMS3$^-$]	(2^{-2})	
8	SMCS2	=	SMCS2$^-$	+	[TMG2	-	ATMG2	-	GND	-	SMCS2$^-$]	(2^{-2})	
9	SGAP2	=	SGAP2$^-$	+	[-SMGAP	+	GS02	+	GND	-	SGAP2$^-$]	(2^{-2})	& CGAP2$^+$ = SGAP2$^+$ - (TXP) (SMCS2$^+$)
10	SMMX2	=	SMMX2$^-$	+	[BMX2	-	TMX20	-	GND	-	SMMX2$^-$]	(2^{-2})	& DI15 Battery Check
11	SMAIR	=	SMAIR$^-$	+	[BAIR	-	TAIR0	-	GND	-	SMAIR$^-$]	(2^{-2})	
12	SMBAT	=	SMBAT$^-$	+	[BBAT	-	TBAT0	-	GND	-	SMBAT$^-$]	(2^{-2})	
13	SMMX1	=	SMMX1$^-$	+	[BMX1	-	TMX10	-	GND	-	SMMX1$^-$]	(2^{-2})	
14	SMTCM	=	SMTCM$^-$	+	[BTCM	-	TCM0	-	GND	-	SMTCM$^-$]	(2^{-2})	

$THERM_{15}$

(i)	TCALST				A2LST	TMLST		ATLST			A3LST	TMPK								
0	TCG1$^+$	=	TCG1$^-$	-	[(AG2)	(TMG1$^-$	-	ATMG1	-	GND) -	(AG3)	(TMPK$_0$)]	(2^9)	TMPK$_0$	=	TMG1	-	ATMG1	-	G
1	TCG2$^+$	=	TCG2$^-$	-	[(AG2)	(TMG2$^-$	-	ATMG2	-	GND) -	(AG3)	(TMPK$_1$)]	(2^9)	TMPK$_1$	=	TMG2	-	ATMG2	-	G
2	TCCA1$^+$	=	TCCA1$^-$	-	[(-AC2)	(TMCA1$^-$	-	ATMC1	-	GND) -	(-AC3)	(TMPK$_2$)]	(2^9)	TMPK$_2$	=	TMCA1	-	ATMC1	-	G
3	TCCA2$^+$	=	TCCA2$^-$	-	[(-AC2)	(TMCA2$^-$	-	ATMC2	-	GND) -	(-AC3)	(TMPK$_3$)]	(2^9)	TMPK$_3$	=	TMCA2	-	ATMC2	-	G
4	TCEMA$^+$	=	TCEMA$^-$	-	[(-AE2)	(TMEMA$^-$	-	ATME	-	GND) -	(-AE3)	(TMPK$_4$)]	(2^9)	TMPK$_4$	=	TMEMA	-	ATME	-	G
5	TCS1$^+$	=	TCS1$^-$	-	[(-AS2)	(TMS1$^-$	-	ATMS1	-	GND) -	(-AS3)	(TMPK$_5$)]	(2^9)	TMPK$_5$	=	TMS1	-	ATMS1	-	G
6	TCS2$^+$	=	TCS2$^-$	-	[(AS2)	(TMS2$^-$	-	ATMS2	-	GND) -	(AS3)	(TMPK$_6$)]	(2^9)	TMPK$_6$	=	TMS2	-	ATMS2	-	G
7	TCS3$^+$	=	TCS3$^-$	-	[(AS2)	(TMS3$^-$	-	ATMS3	-	GND) -	(AS3)	(TMPK$_7$)]	(2^9)	TMPK$_7$	=	TMS3	-	ATMS3	-	G

BKG (1-SEC RATE)

SMRF$^+$	=	SMRF$^-$ + (-TMRF1 + GND - SMRF$^-$)(2^{-2})
DVR$^+$	=	(PVPV) (SMRF$^+$ - VROLD)
ATMG1	=	TC01 + (DVR$^+$) (0.50726)
ATMG2	=	TC02 + (DVR$^+$) (0.50726)
ATMC1	=	TSC1 + (DVR$^+$)
ATMC2	=	TSC2 + (DVR$^+$)
ATME	=	TSE + (DVR$^+$)
ATMS1	=	TSS1 + (DVR$^+$)
ATMS2	=	TSS2 + (DVR$^+$)
ATMS3	=	TSS3 + (DVR$^+$)

P

& $CGAP1^+ = SGAP1^+$ -(TXP) $(SMCS1^+)$
& DI15 Battery Check

& $CGAP2^+ = SGAP2^+$ - (TXP) $(SMCS2^+)$
& DI15 Battery Check

$Loc - SM_i$	Input	–	Loc	Set Point	–	Loc
2D	TMG1	=	083B	ATMG1	=	0D82
2E AND 3C	SMGAP	=	0830	GS01	=	0C26
2F	TMCA1	=	083D	ATMC1	=	0D84
30	TMCA2	=	083E	ATMC2	=	0D85
31	TMEMA	=	083F	ATME	=	0D86
32	TMS1	=	085A	ATMS1	=	0D87
33	TMS2	=	085B	ATMS2	=	0D88
34	TMS3	=	085C	ATMS3	=	0D89
35	TMG2	=	083C	ATMG2	=	0D83
36 AND 3D	SMGAP	=	0830	GS02	=	0C27
37	BMX2	=	0840	TMX20	=	0C35
38	BAIR	=	085D	TAIR0	=	0C36
39	BBAT	=	085E	TBAT0	=	0C37
3A	BMX1	=	085F	TMX10	=	0C34
3B	BTCM	=	0860	TCM0	=	0C38

TMPK

$(TMPK_0)] (2^9)$	$TMPK_0$	=	TMG1	-	ATMG1	-	GND
$(TMPK_1)] (2^9)$	$TMPK_1$	=	TMG2	-	ATMG2	-	GND
$(TMPK_2)] (2^9)$	$TMPK_2$	=	TMCA1	-	ATMC1	-	GND
$(TMPK_3)] (2^9)$	$TMPK_3$	=	TMCA2	-	ATMC2	-	GND
$(TMPK_4)] (2^9)$	$TMPK_4$	=	TMEMA	-	ATME	-	GND
$(TMPK_5)] (2^9)$	$TMPK_5$	=	TMS1	-	ATMS1	-	GND
$(TMPK_6)] (2^9)$	$TMPK_6$	=	TMS2	-	ATMS2	-	GND
$(TMPK_7)] (2^9)$	$TMPK_7$	=	TMS3	-	ATMS3	-	GND

Input		Loc	Set Point		Loc	Output		Loc
TMG1	=	083B	ATMG1	=	0D82	TCG1	=	0804
TMG2	=	083C	ATMG2	=	0D83	TCG2	=	0805
TMCA1	=	083D	ATMC1	=	0D84	TCCA1	=	0809
TMCA2	=	083E	ATMC2	=	0D85	TCCA2	=	080A
TMEMA	=	083F	ATME	=	0D86	TCEMA	=	0808
TMS1	=	085A	ATMS1	=	0D87	TCS1	=	080B
TMS2	=	085B	ATMS2	=	0D88	TCS2	=	0806
TMS3	=	085C	ATMS3	=	0D89	TCS3	=	0807

		Loc
TMRF1	=	0861

Set Point	=	Loc
TC01	=	0C28
TC02	=	0C29
TSC1	=	0C2A
TSC2	=	0C2B
TSE	=	0C2C
TSS1	=	0C2D
TSS2	=	0C2E
TSS3	=	0C2F

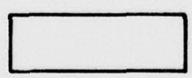
APPENDIX H

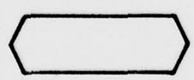
BACKGROUND PROGRAM

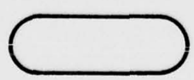
DETAILED FLOW CHARTS

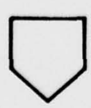
FLOW CHART SYMBOLS


ENTRY POINT OR CONNECTOR

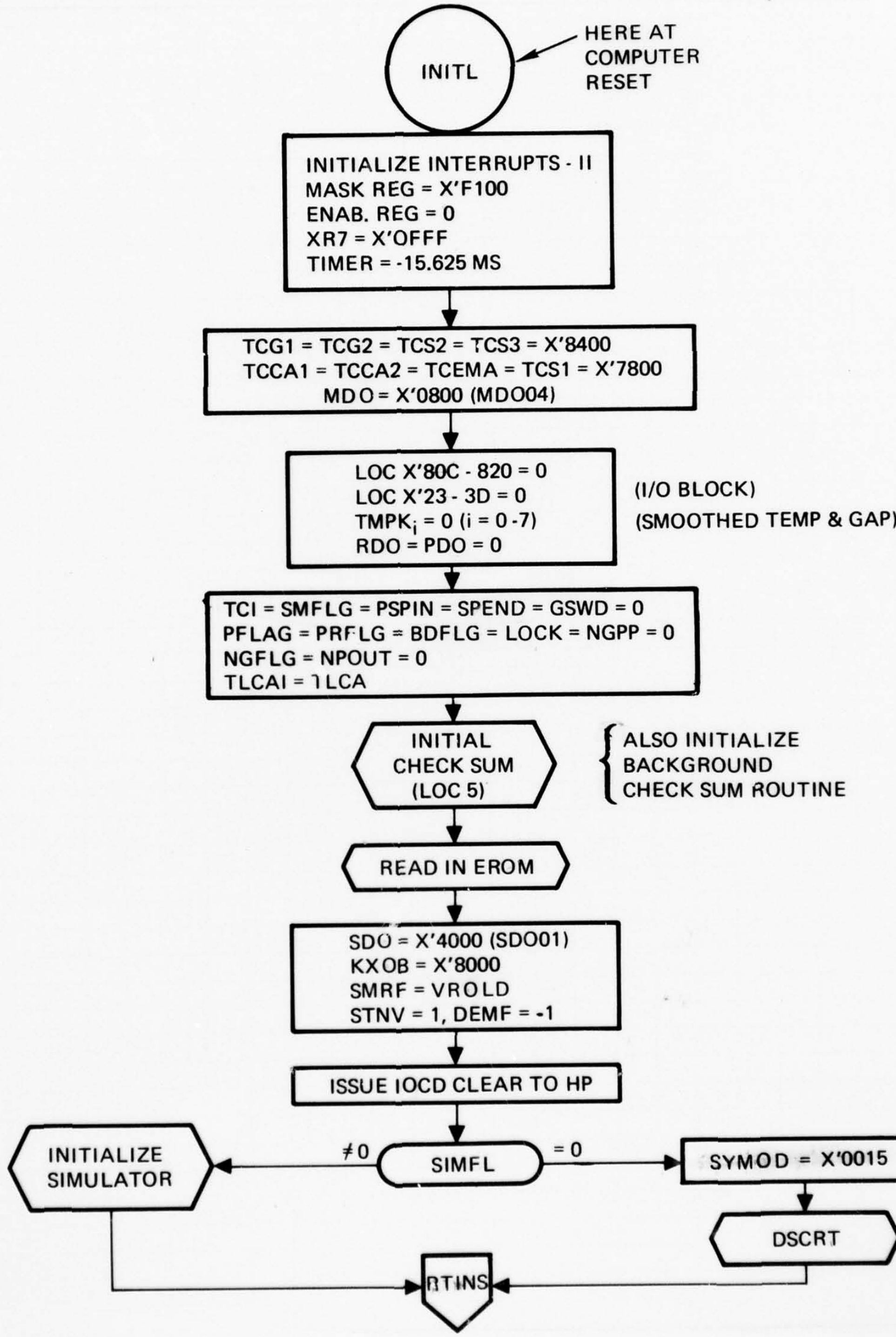

PROCESS

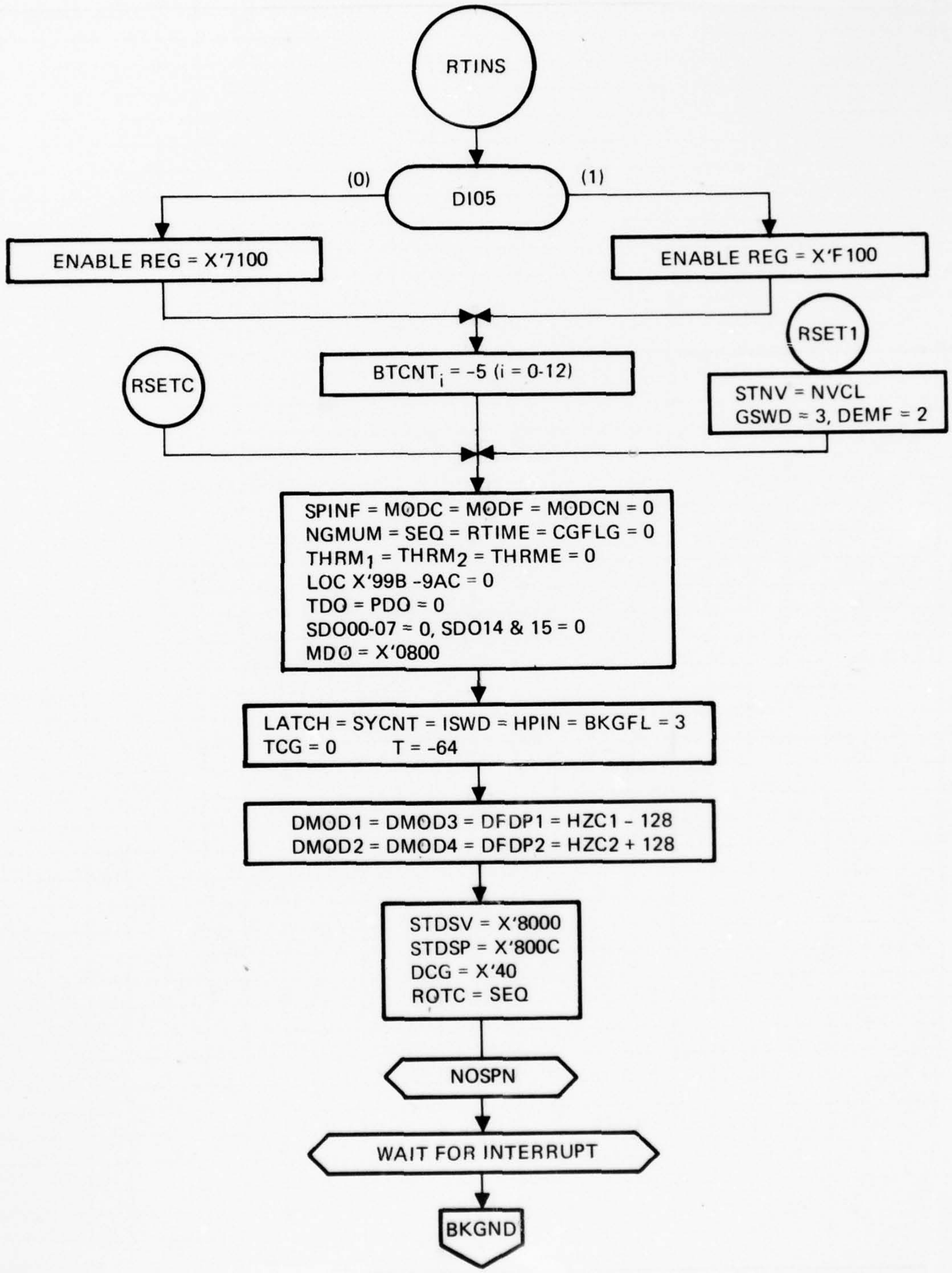

SUBROUTINE


BRANCH POINT


OFF-PAGE CONNECTOR

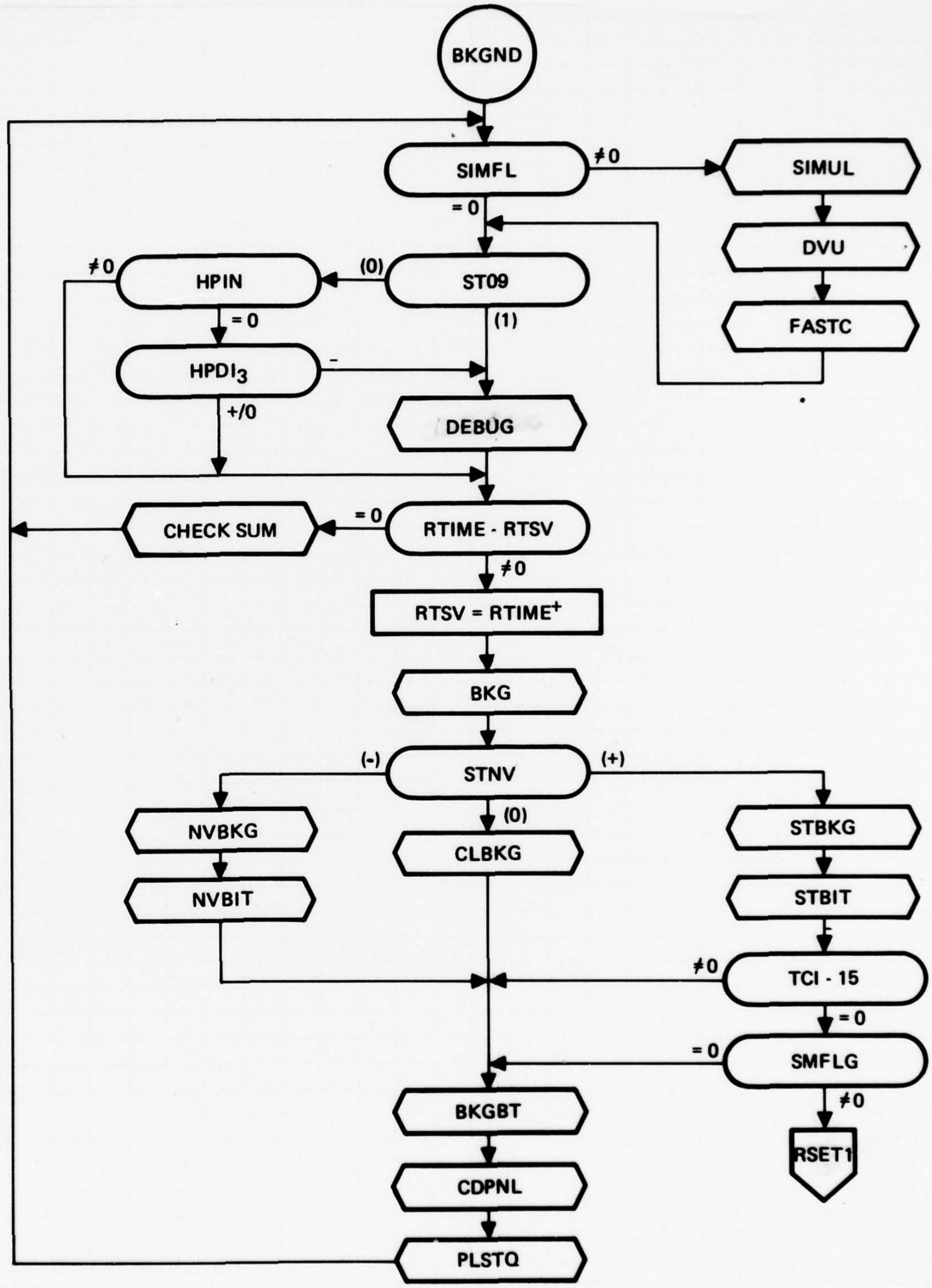

OFF-PAGE BRANCH

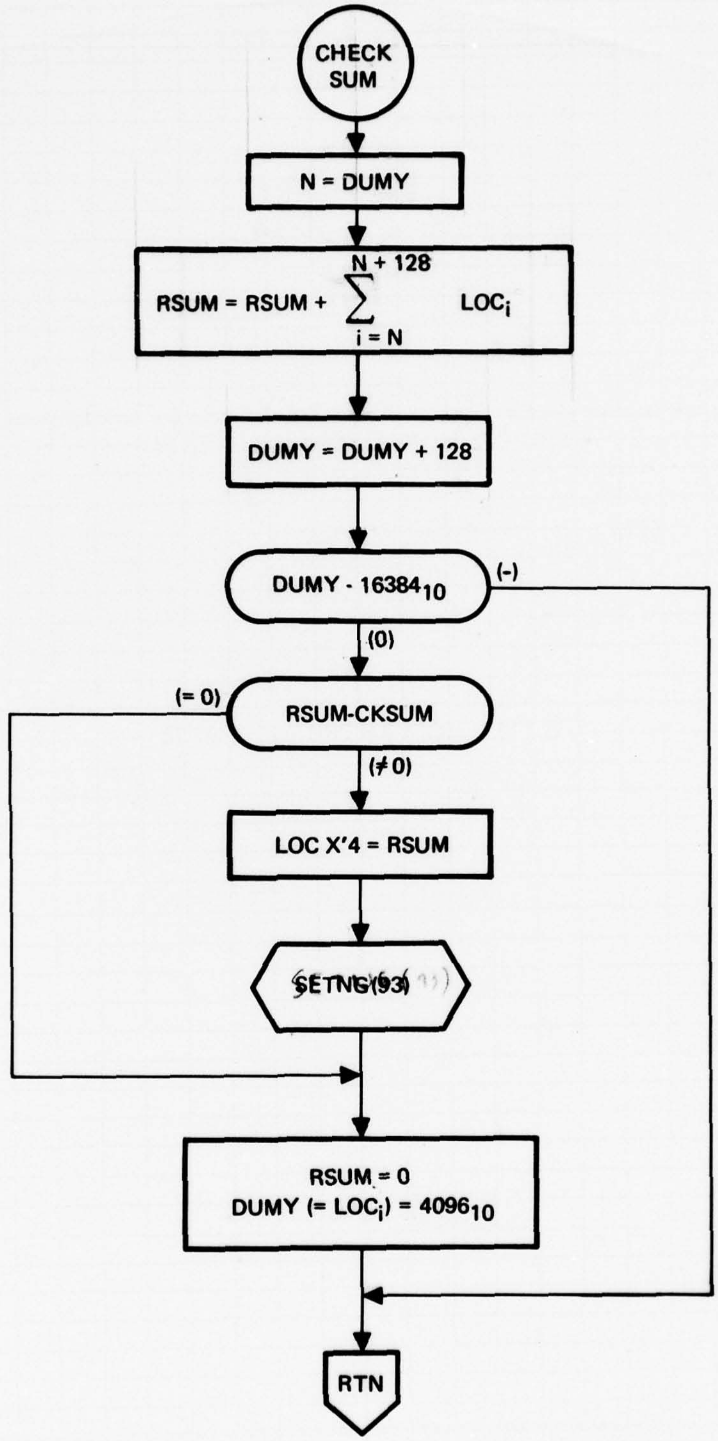

INITL
HERE AT COMPUTER RESET
INITIALIZE INTERRUPTS - II
MASK REG = X'F100
ENAB. REG = 0
XR7 = X'OFFF
TIMER = -15.625 MS
TCG1 = TCG2 = TCS2 = TCS3 = X'8400
TCCA1 = TCCA2 = TCEMA = TCS1 = X'7800
MDO = X'0800 (MDO04)
LOC X'80C - 820 = 0
LOC X'23 - 3D = 0
TMPK$_i$ = 0 (i = 0-7)
RDO = PDO = 0
(I/O BLOCK)
(SMOOTHED TEMP & GAP)
TCI = SMFLG = PSPIN = SPEND = GSWD = 0
PFLAG = PRFLG = BDFLG = LOCK = NGPP = 0
NGFLG = NPOUT = 0
TLCAI = TLCA
INITIAL CHECK SUM (LOC 5)
ALSO INITIALIZE BACKGROUND CHECK SUM ROUTINE
READ IN EROM
SDO = X'4000 (SDO01)
KXOB = X'8000
SMRF = VROLD
STNV = 1, DEMF = -1
ISSUE IOCD CLEAR TO HP
INITIALIZE SIMULATOR
≠0
SIMFL
= 0
SYMOD = X'0015
DSCRT
RTINS

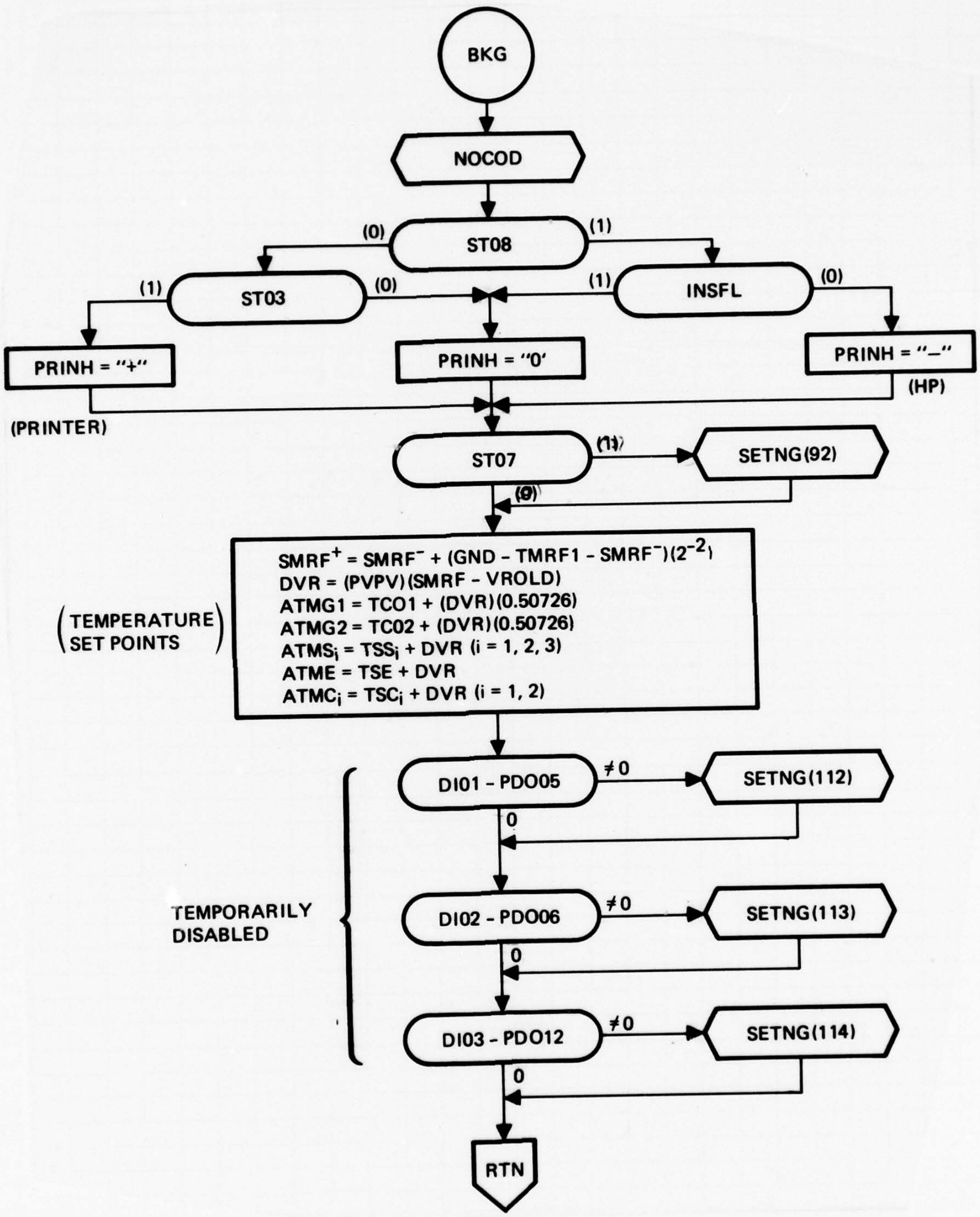

RTINS
DI05
(0)
(1)
ENABLE REG = X'7100
ENABLE REG = X'F100
RSET1
RSETC
BTCNT$_i$ = -5 (i = 0-12)
STNV = NVCL
GSWD = 3, DEMF = 2
SPINF = MODC = MODF = MODCN = 0
NGMUM = SEQ = RTIME = CGFLG = 0
THRM$_1$ = THRM$_2$ = THRME = 0
LOC X'99B -9AC = 0
TDO = PDO = 0
SDO00-07 = 0, SDO14 & 15 = 0
MDO = X'0800
LATCH = SYCNT = ISWD = HPIN = BKGFL = 3
TCG = 0 T = -64
DMOD1 = DMOD3 = DFDP1 = HZC1 - 128
DMOD2 = DMOD4 = DFDP2 = HZC2 + 128
STDSV = X'8000
STDSP = X'800C
DCG = X'40
ROTC = SEQ
NOSPN
WAIT FOR INTERRUPT
BKGND

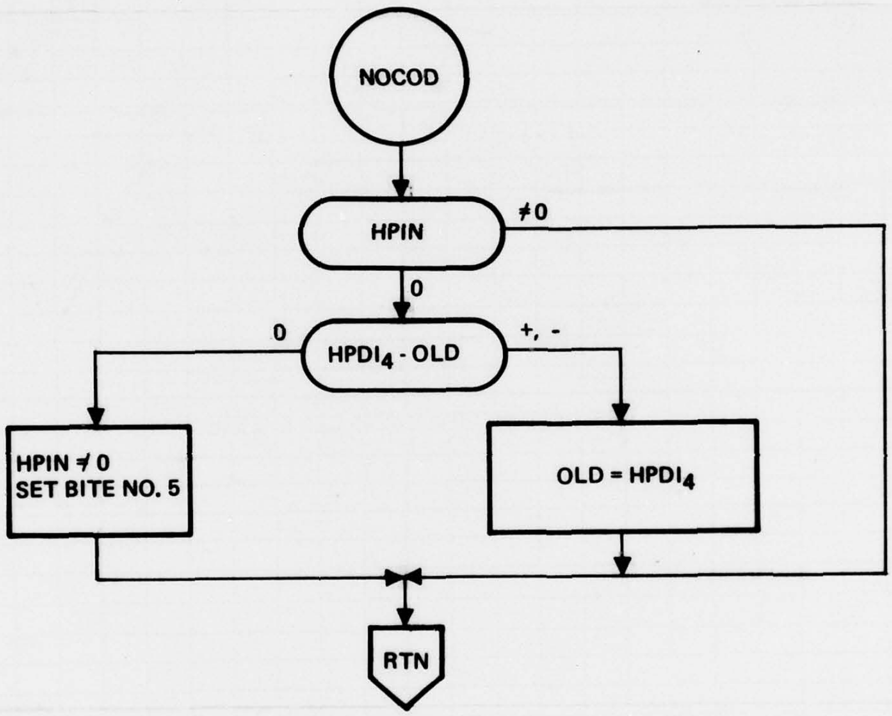
AD-A048 001 ROCKWELL INTERNATIONAL ANAHEIM CALIF AUTONETICS GROUP F/G 17/7
MICRO NAVIGATOR (MICRON) PHASE 2B. VOLUME II - APPENDICES.(U)
AUG 77 J M MILLER, A P ANDREWS, T F BRASHER F33615-75-C-1301
UNCLASSIFIED C75-787/201-VOL-2 AFAL-TR-77-138-VOL-2 NL

2 OF 4
AD
A048001

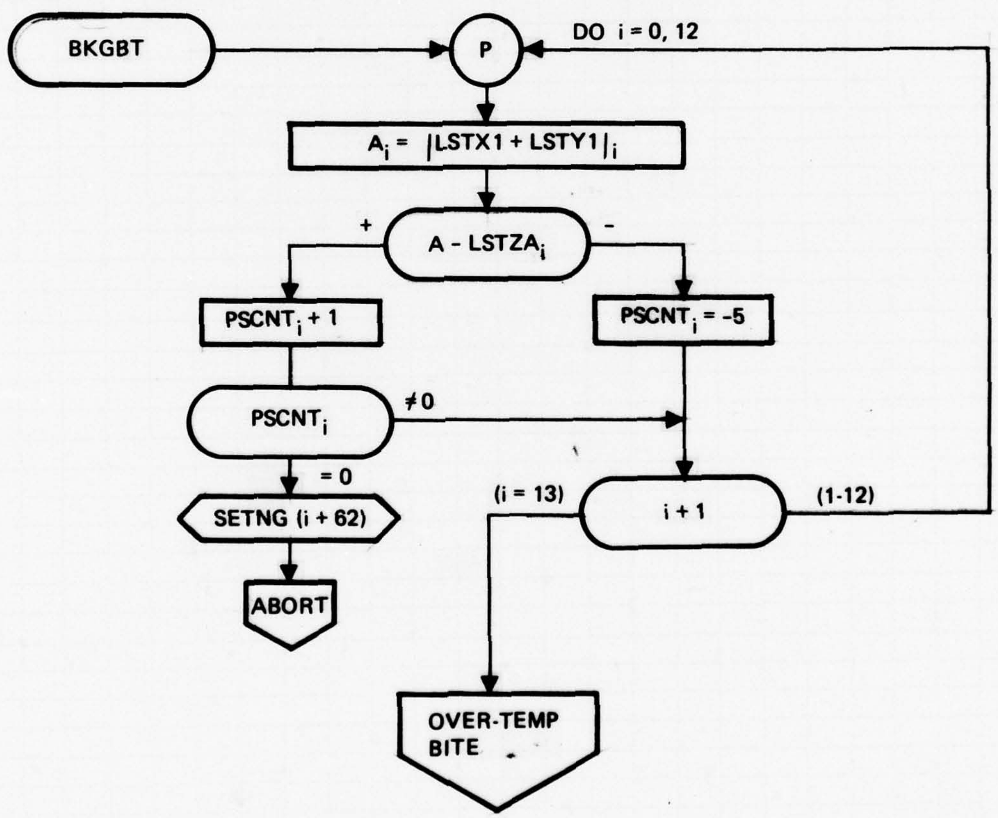

BKGND
SIMFL
≠0
SIMUL
DVU
FASTC
= 0
(0)
ST09
(1)
≠0
HPIN
= 0
HPDI3
-
+/0
DEBUG
CHECK SUM
= 0
RTIME - RTSV
≠0
RTSV = RTIME+
BKG
(-)
STNV
(+)
(0)
NVBKG
CLBKG
STBKG
NVBIT
STBIT
≠0
TCI - 15
= 0
= 0
SMFLG
≠0
RSET1
BKGBT
CDPNL
PLSTQ


CHECK SUM
N = DUMY
RSUM = RSUM + $\sum_{i=N}^{N+128}$ LOC$_i$
DUMY = DUMY + 128
DUMY - 16384_{10}
(-)
(0)
RSUM-CKSUM
(= 0)
(≠ 0)
LOC X'4 = RSUM
SETNG(93)
RSUM = 0
DUMY (= LOC$_i$) = 4096_{10}
RTN

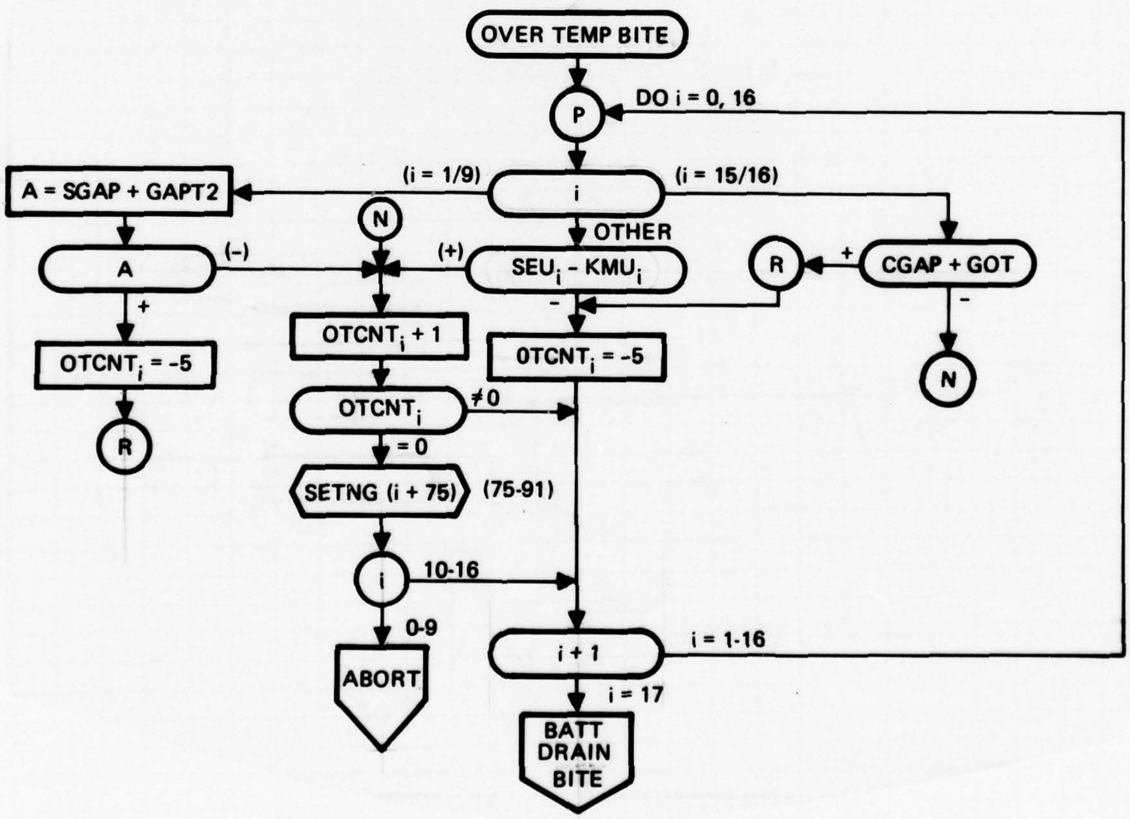

BKG
NOCOD
ST08
(0)
(1)
ST03
(1)
(0)
INSFL
(1)
(0)
PRINH = "+"
PRINH = "0'
PRINH = "–"
(PRINTER)
(HP)
ST07
(1)
SETNG(92)
(0)
SMRF+ = SMRF– + (GND – TMRF1 – SMRF–)(2-2)
DVR = (PVPV)(SMRF – VROLD)
ATMG1 = TCO1 + (DVR)(0.50726)
ATMG2 = TC02 + (DVR)(0.50726)
ATMSi = TSSi + DVR (i = 1, 2, 3)
ATME = TSE + DVR
ATMCi = TSCi + DVR (i = 1, 2)
(TEMPERATURE SET POINTS)
DI01 – PDO05
≠0
SETNG(112)
0
DI02 – PDO06
≠0
SETNG(113)
0
DI03 – PDO12
≠0
SETNG(114)
0
TEMPORARILY DISABLED
RTN

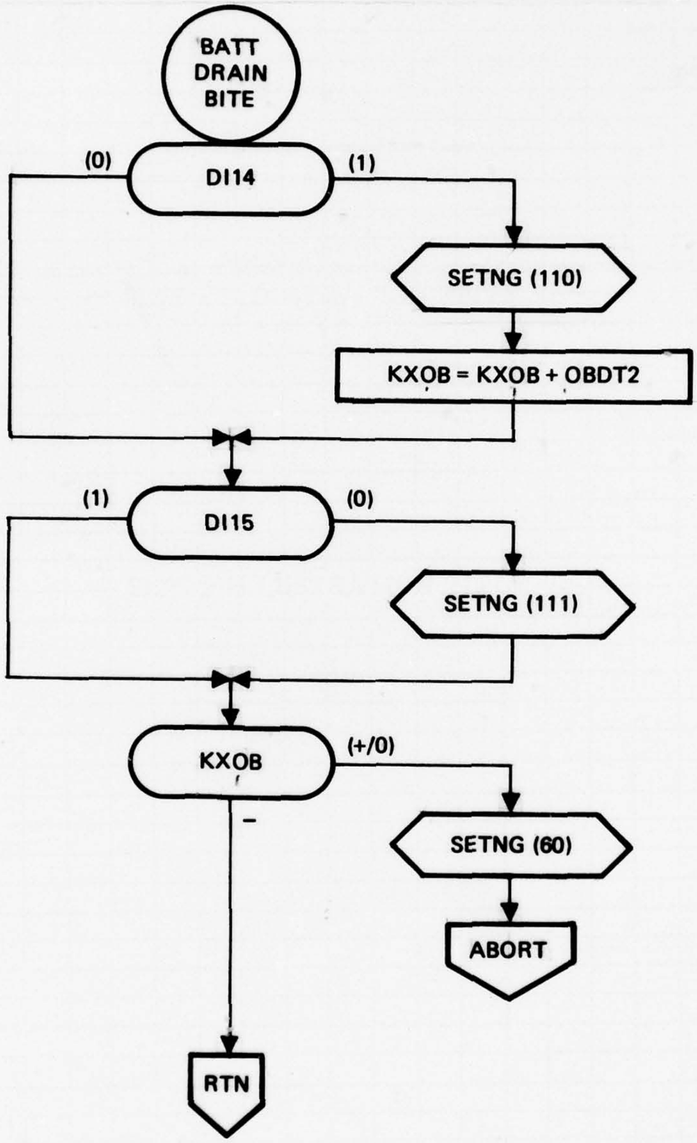

NOCOD
HPIN
≠0
0
0
$HPDI_4$ - OLD
+, -
HPIN ≠ 0
SET BITE NO. 5
OLD = $HPDI_4$
RTN

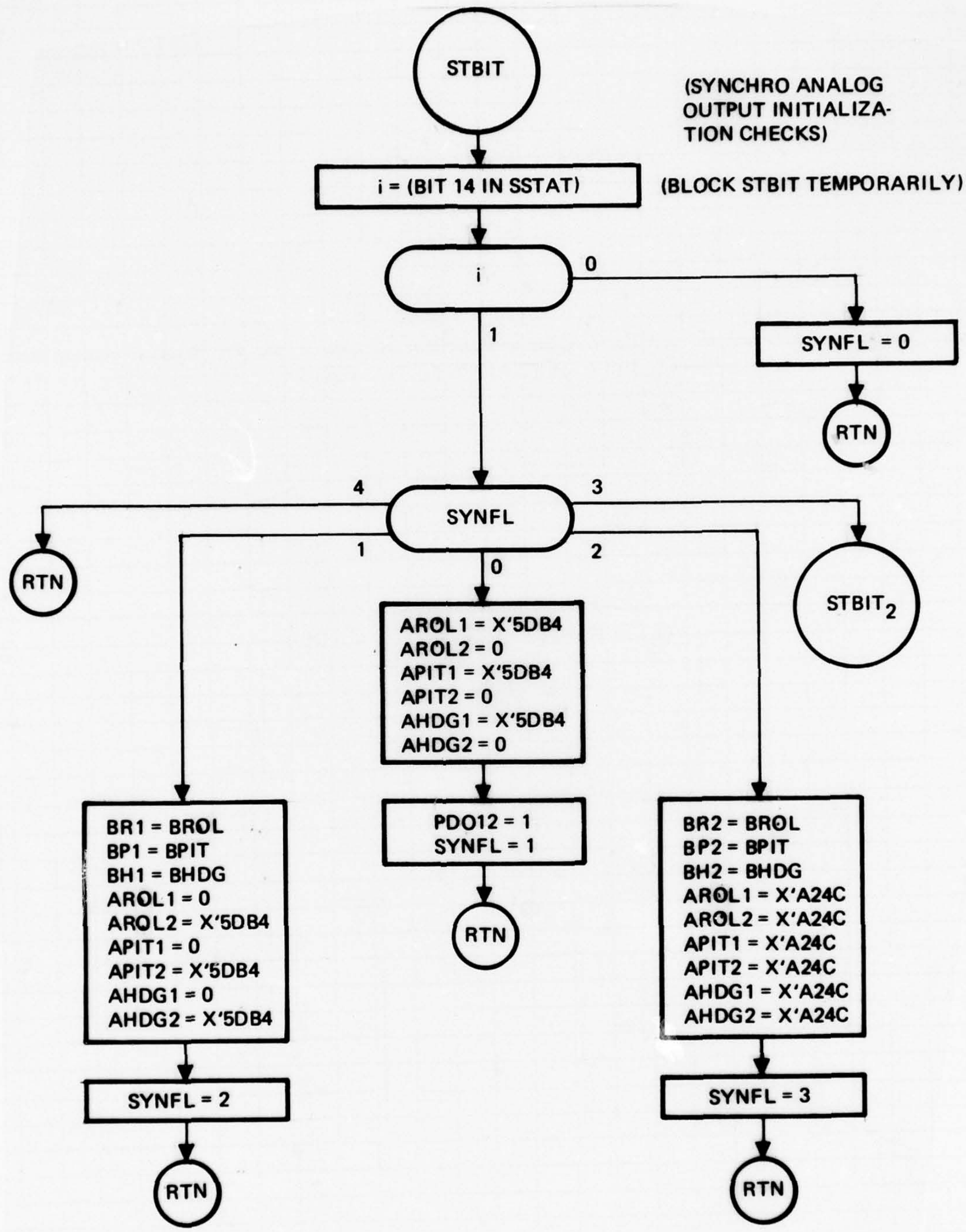
ID	LSTX1	LSTY1	LSTZA	i
62	B24	-24.0	3.6	0
63	B15C	-15.0	2.25	1
64	B15	-15.0	6.0	2
65	B7	+ 7.5	1.125	3
66	BM7	- 7.5	1.125	4
67	BSC	+ 5.2	0.78	5
68	B12	+12.0	1.8	6
69	BM12	-12.0	1.8	7
70	B15S	+15.0	2.25	8
71	BM15S	-15.0	2.25	9
72	POS5	+ 5.0	2.0	10
73	MIN5	- 5.0	2.0	11
74	GND	0	1.0	12

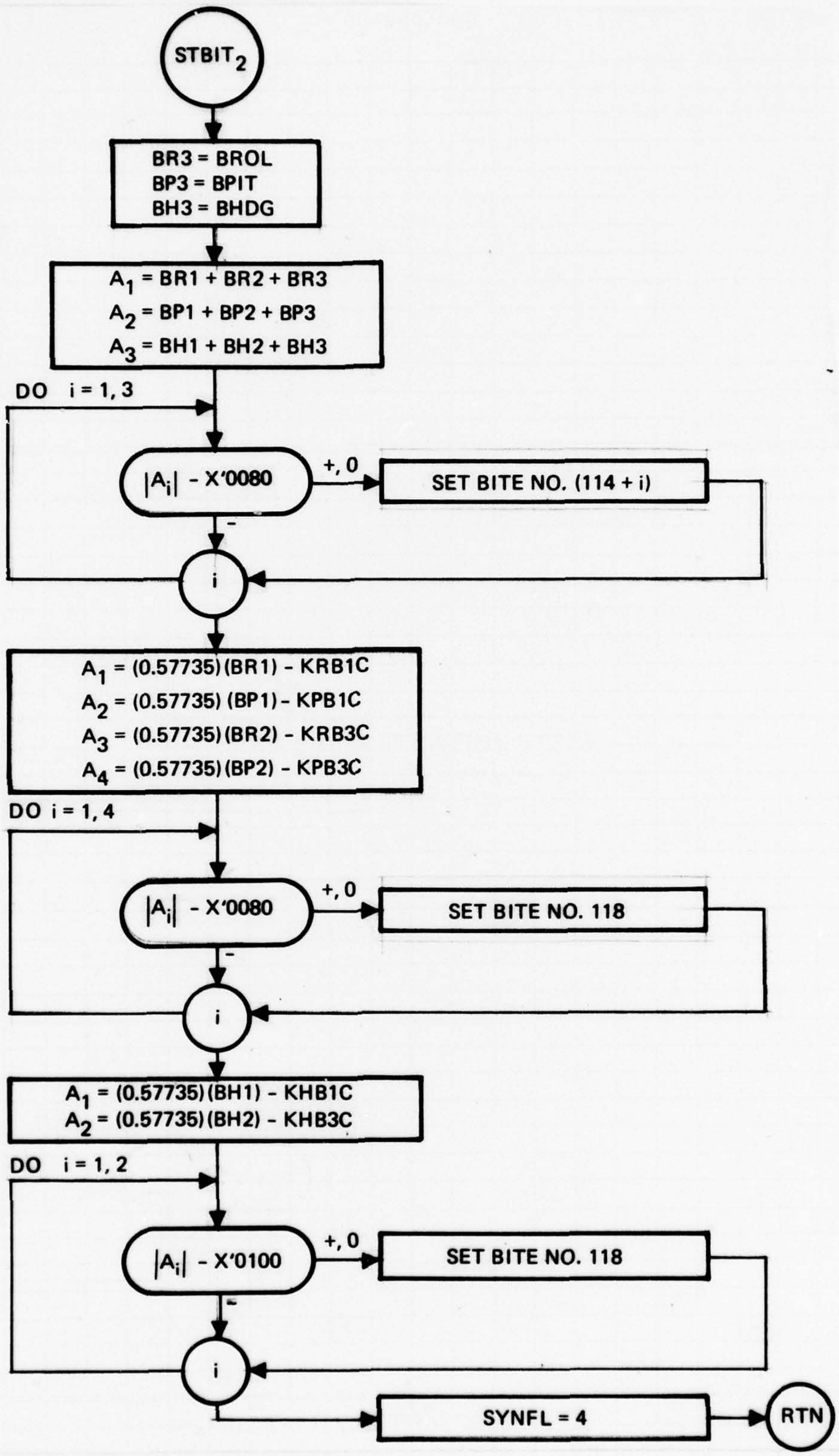


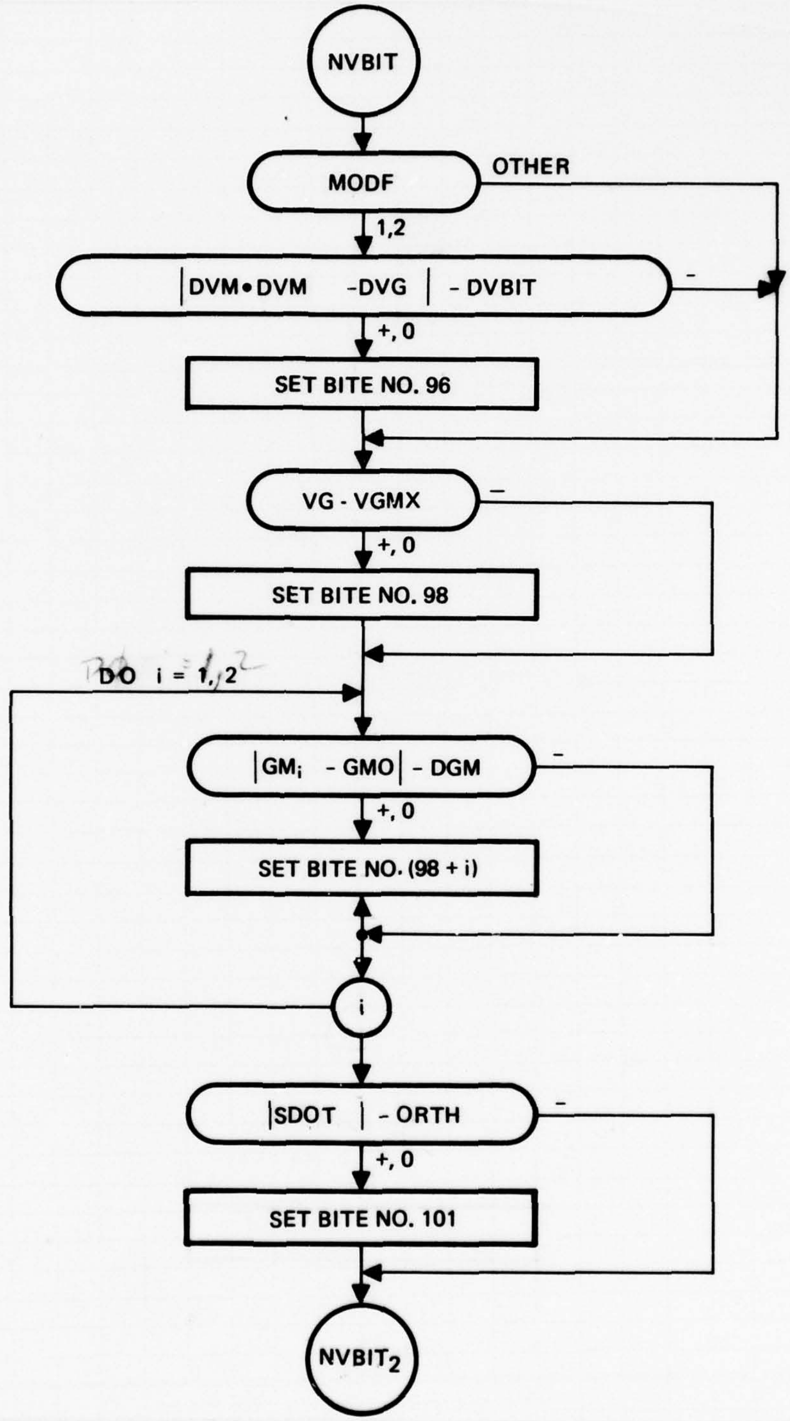
ID	SEU	KMU		i
75	SMCS1	$30^{\circ}F$	(KSMCS)	0
76	SGAP1	15μIN.	(GAPT2)	1
77	SMCA1	$30^{\circ}F$	(KMUX2)	2
78	SMCA2	$30^{\circ}F$	(KMUX2)	3
79	SMEMA	$30^{\circ}F$	(KMUX2)	4
80	SMS1	$30^{\circ}F$	(KMUX1)	5
81	SMS2	$30^{\circ}F$	(KMUX1)	6
82	SMS3	$30^{\circ}F$	(KMUX1)	7
83	SMCS2	$30^{\circ}F$	(KSMCS)	8
84	SGAP2	15μIN.	(GAPT2)	9
85	SMMX2	$50^{\circ}F$	(KINT)	10
86	SMAIR	$50^{\circ}F$	(KAIR)	11
87	SMBAT	$50^{\circ}F$	(KBAT)	12
88	SMMX1	$50^{\circ}F$	(KINT)	13
89	SMTCM	$50^{\circ}F$	(KINT)	14
90	CGAP1	2μIN.	(GOT)	15
91	CGAP2	2μIN.	(GOT)	16

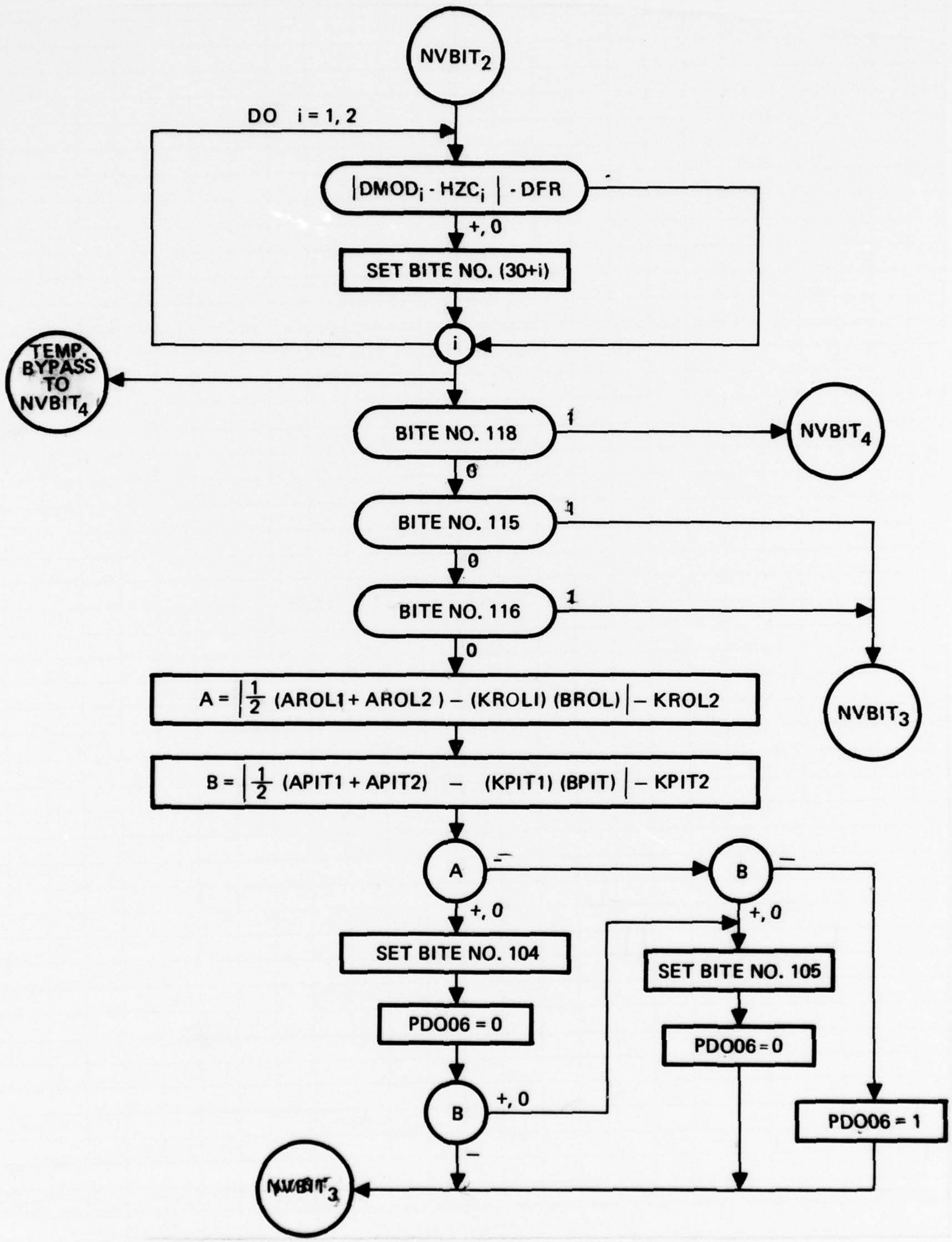


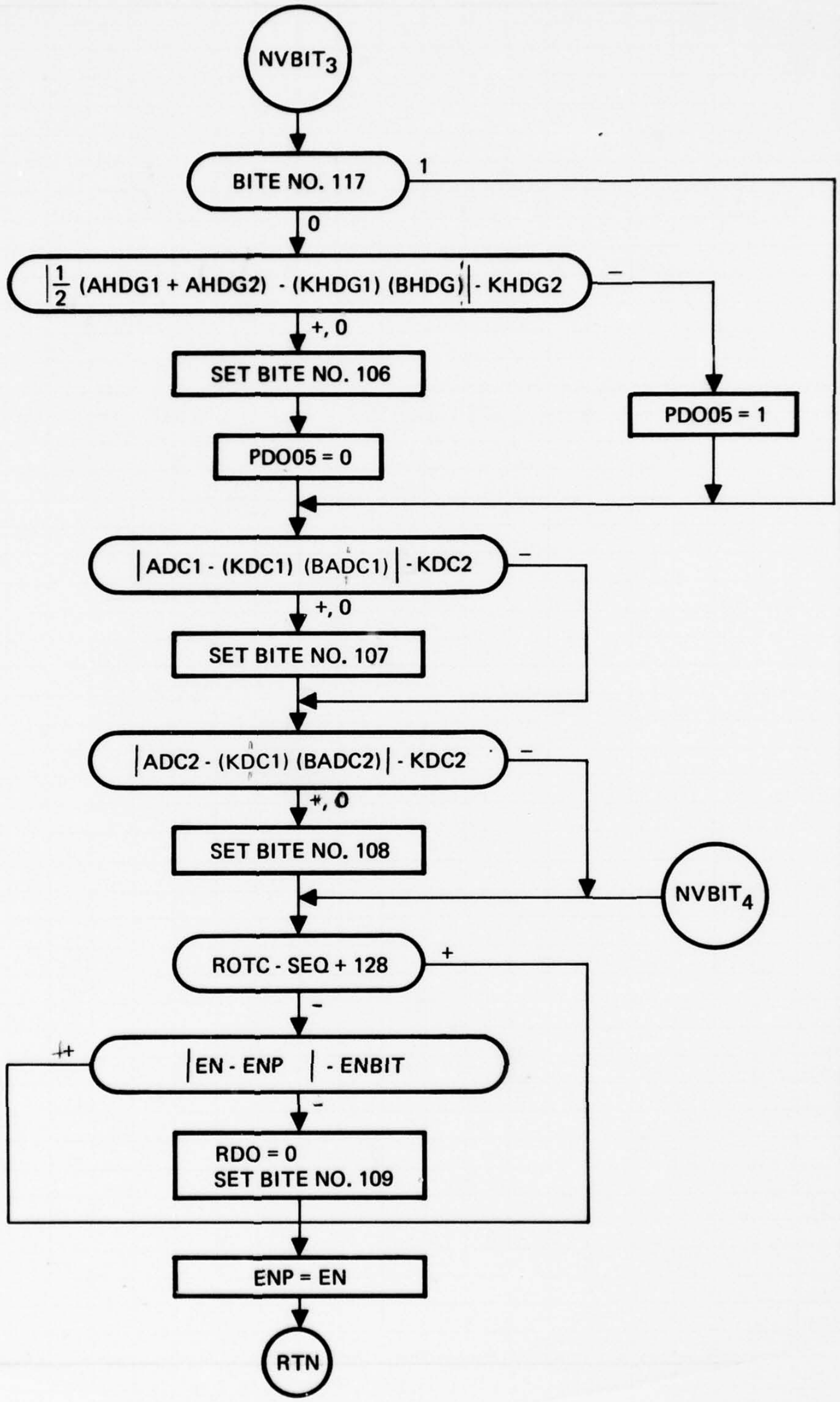

BATT
DRAIN
BITE
(0)
DI14
(1)
SETNG (110)
KXOB = KXOB + OBDT2
(1)
DI15
(0)
SETNG (111)
KXOB
(+/0)
–
SETNG (60)
ABORT
RTN


STBIT
(SYNCHRO ANALOG OUTPUT INITIALIZATION CHECKS)
i = (BIT 14 IN SSTAT)
(BLOCK STBIT TEMPORARILY)
i
0
1
SYNFL = 0
RTN
SYNFL
4
3
1
0
2
RTN
STBIT2
AROL1 = X'5DB4
AROL2 = 0
APIT1 = X'5DB4
APIT2 = 0
AHDG1 = X'5DB4
AHDG2 = 0
PDO12 = 1
SYNFL = 1
RTN
BR1 = BROL
BP1 = BPIT
BH1 = BHDG
AROL1 = 0
AROL2 = X'5DB4
APIT1 = 0
APIT2 = X'5DB4
AHDG1 = 0
AHDG2 = X'5DB4
SYNFL = 2
RTN
BR2 = BROL
BP2 = BPIT
BH2 = BHDG
AROL1 = X'A24C
AROL2 = X'A24C
APIT1 = X'A24C
APIT2 = X'A24C
AHDG1 = X'A24C
AHDG2 = X'A24C
SYNFL = 3
RTN

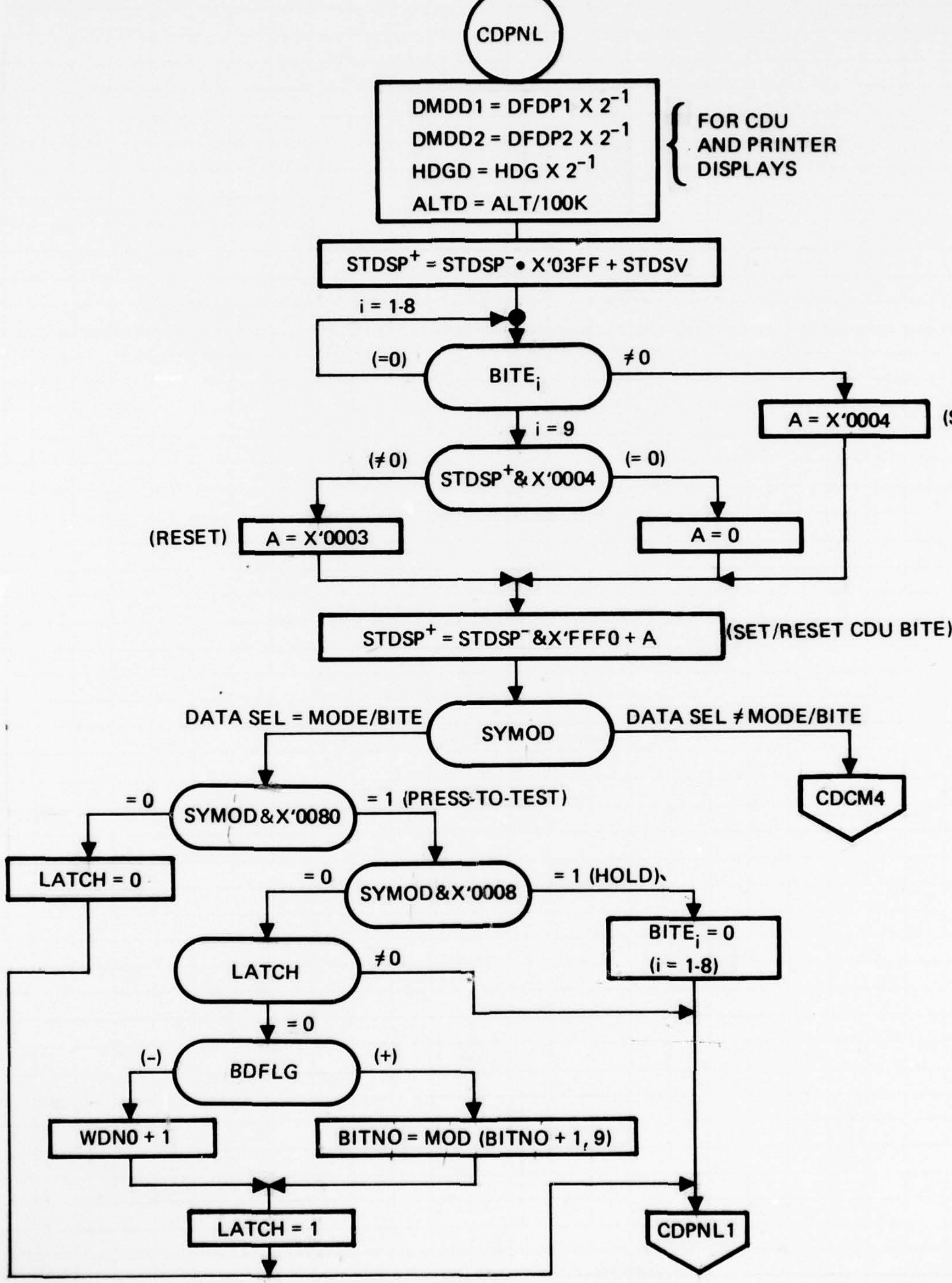

STBIT2
BR3 = BROL
BP3 = BPIT
BH3 = BHDG
A1 = BR1 + BR2 + BR3
A2 = BP1 + BP2 + BP3
A3 = BH1 + BH2 + BH3
DO i = 1, 3
|Ai| - X'0080
+, 0
-
SET BITE NO. (114 + i)
i
A1 = (0.57735) (BR1) - KRB1C
A2 = (0.57735) (BP1) - KPB1C
A3 = (0.57735) (BR2) - KRB3C
A4 = (0.57735) (BP2) - KPB3C
DO i = 1, 4
|Ai| - X'0080
+, 0
-
SET BITE NO. 118
i
A1 = (0.57735) (BH1) - KHB1C
A2 = (0.57735) (BH2) - KHB3C
DO i = 1, 2
|Ai| - X'0100
+, 0
-
SET BITE NO. 118
i
SYNFL = 4
RTN

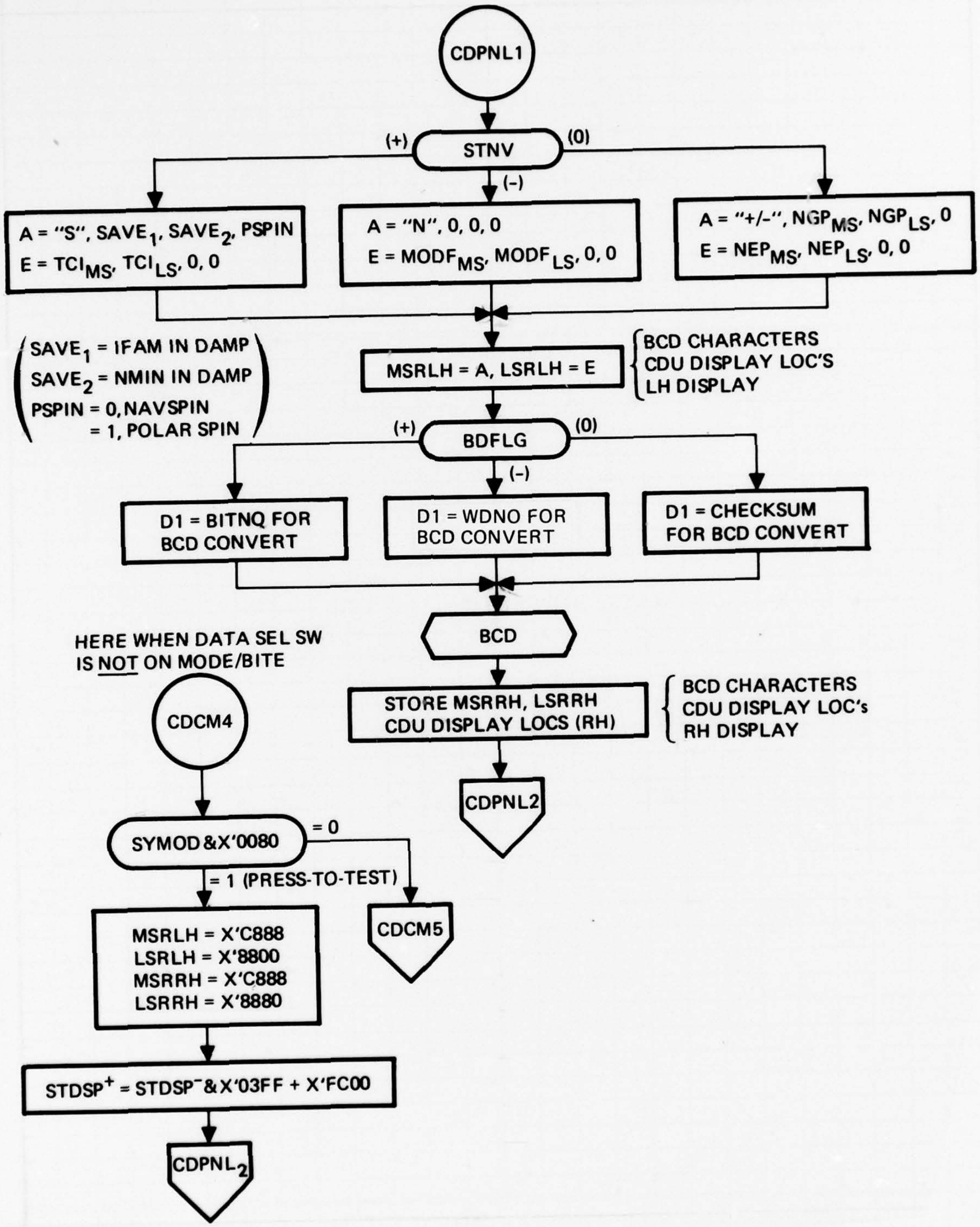

NVBIT
MODF
OTHER
1,2
|DVM•DVM -DVG| - DVBIT
-
+, 0
SET BITE NO. 96
VG - VGMX
-
+, 0
SET BITE NO. 98
DO i = 1, 2
|GMi - GMO| - DGM
-
+, 0
SET BITE NO. (98 + i)
i
|SDOT| - ORTH
-
+, 0
SET BITE NO. 101
NVBIT2

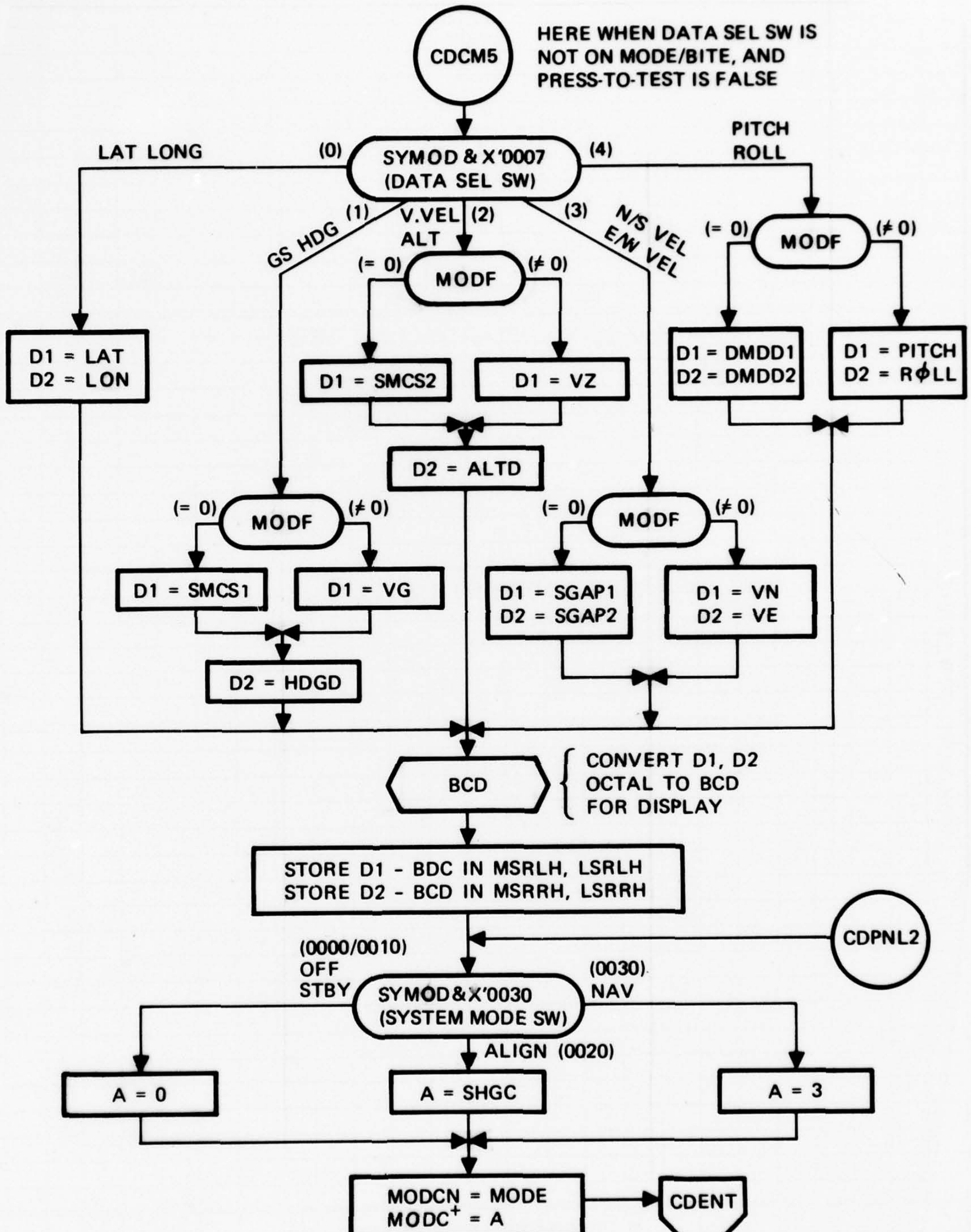

NVBIT2
DO i = 1, 2
|DMODi - HZCi | - DFR
+, 0
SET BITE NO. (30+i)
i
TEMP. BYPASS TO NVBIT4
BITE NO. 118
1
NVBIT4
0
BITE NO. 115
1
0
BITE NO. 116
1
0
A = |1/2 (AROL1 + AROL2) – (KROLI) (BROL)| – KROL2
NVBIT3
B = |1/2 (APIT1 + APIT2) – (KPIT1) (BPIT)| – KPIT2
A
–
B
–
+, 0
+, 0
SET BITE NO. 104
SET BITE NO. 105
PDO06 = 0
PDO06 = 0
B
+, 0
PDO06 = 1
–
NVBIT3

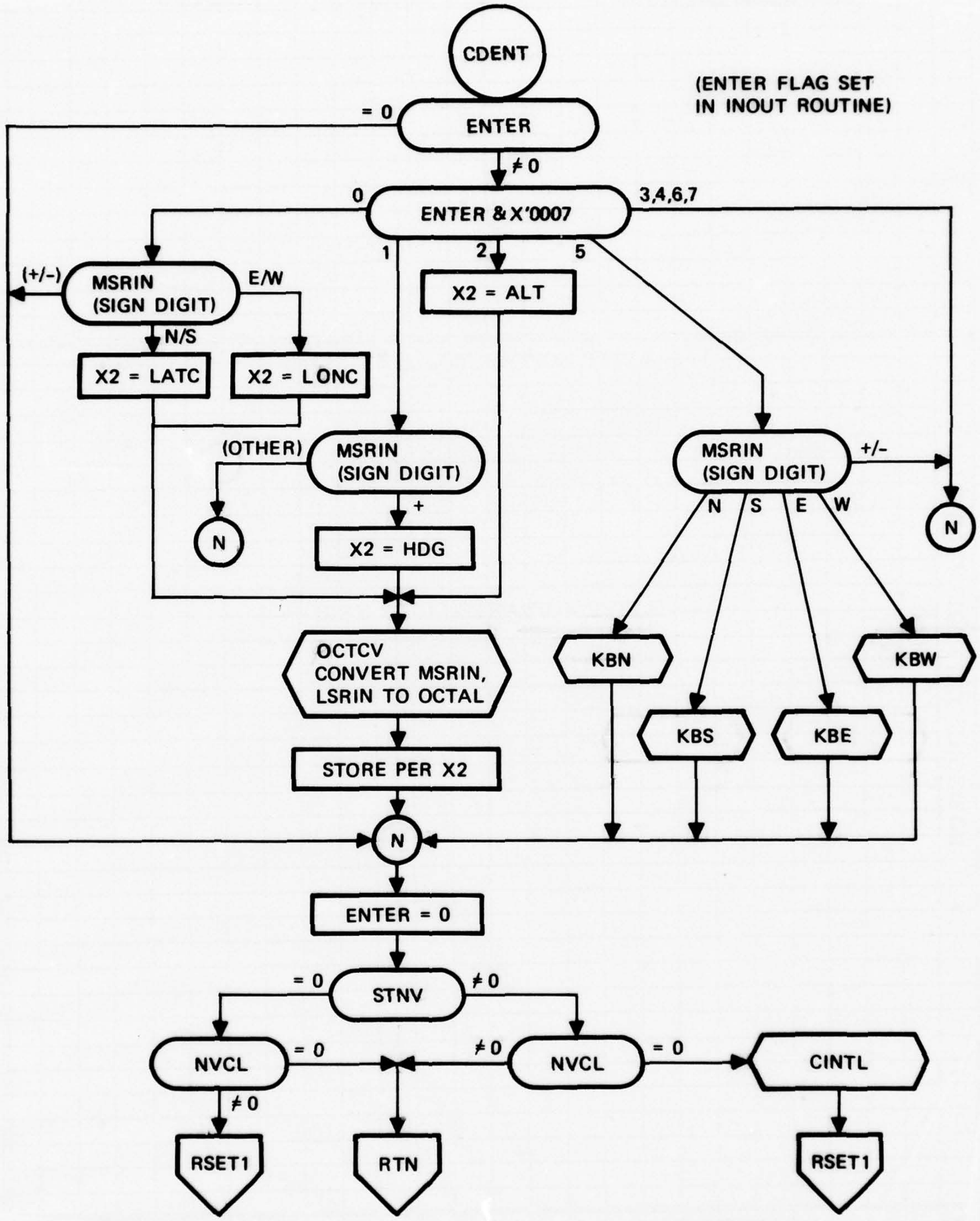


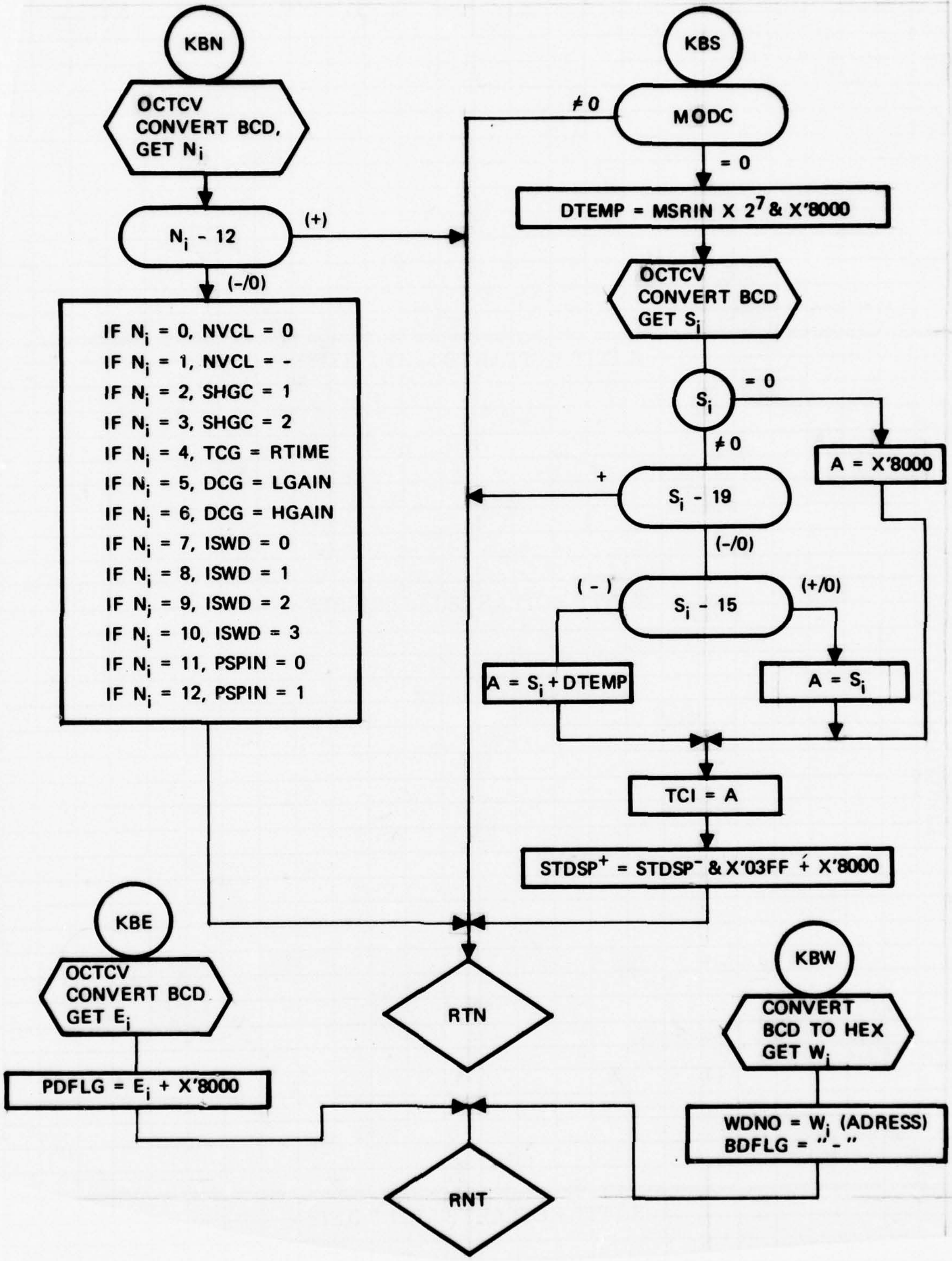
NVBIT3
BITE NO. 117
1
0
|1/2 (AHDG1 + AHDG2) - (KHDG1) (BHDG)| - KHDG2
–
+, 0
SET BITE NO. 106
PDO05 = 1
PDO05 = 0
|ADC1 - (KDC1) (BADC1)| - KDC2
–
+, 0
SET BITE NO. 107
|ADC2 - (KDC1) (BADC2)| - KDC2
–
+, 0
SET BITE NO. 108
NVBIT4
ROTC - SEQ + 128
+
–
+
|EN - ENP| - ENBIT
–
RDO = 0
SET BITE NO. 109
ENP = EN
RTN

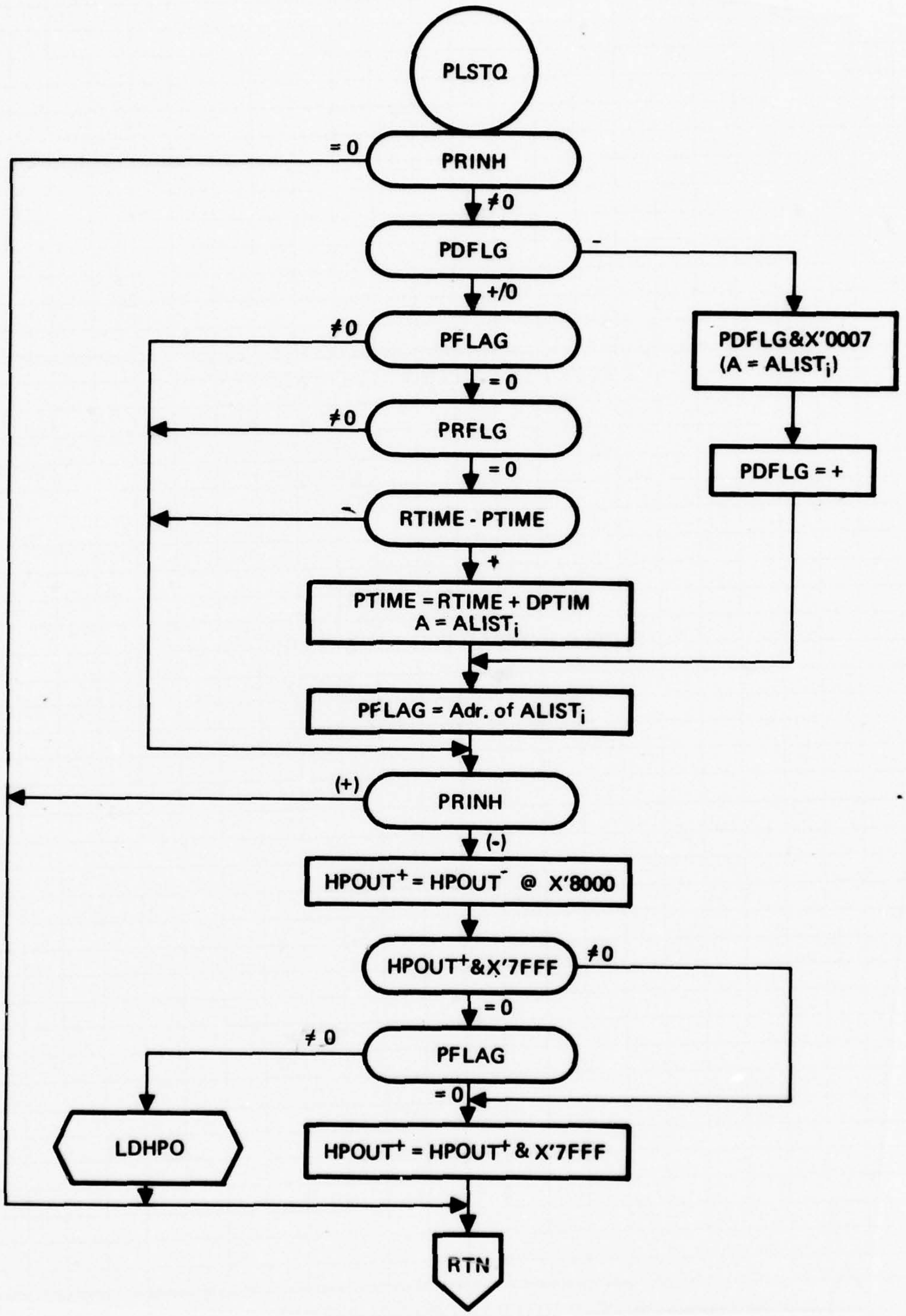

CDPNL
DMDD1 = DFDP1 X 2^-1
DMDD2 = DFDP2 X 2^-1
HDGD = HDG X 2^-1
ALTD = ALT/100K
FOR CDU AND PRINTER DISPLAYS
STDSP+ = STDSP- • X'03FF + STDSV
i = 1-8
(=0)
BITE_i
≠0
A = X'0004
(SET)
i = 9
(≠0)
STDSP+ & X'0004
(= 0)
(RESET)
A = X'0003
A = 0
STDSP+ = STDSP- & X'FFF0 + A
(SET/RESET CDU BITE)
DATA SEL = MODE/BITE
SYMOD
DATA SEL ≠ MODE/BITE
CDCM4
= 0
SYMOD & X'0080
= 1 (PRESS-TO-TEST)
LATCH = 0
= 0
SYMOD & X'0008
= 1 (HOLD)
BITE_i = 0
(i = 1-8)
LATCH
≠0
= 0
(-)
BDFLG
(+)
WDNO + 1
BITNO = MOD (BITNO + 1, 9)
LATCH = 1
CDPNL1


CDPNL1
STNV
(+)
(0)
(–)
A = "S", SAVE1, SAVE2, PSPIN
E = TCIMS, TCILS, 0, 0
A = "N", 0, 0, 0
E = MODFMS, MODFLS, 0, 0
A = "+/–", NGPMS, NGPLS, 0
E = NEPMS, NEPLS, 0, 0
SAVE1 = IFAM IN DAMP
SAVE2 = NMIN IN DAMP
PSPIN = 0, NAVSPIN
= 1, POLAR SPIN
MSRLH = A, LSRLH = E
BCD CHARACTERS
CDU DISPLAY LOC'S
LH DISPLAY
BDFLG
(+)
(0)
(–)
D1 = BITNQ FOR BCD CONVERT
D1 = WDNO FOR BCD CONVERT
D1 = CHECKSUM FOR BCD CONVERT
BCD
STORE MSRRH, LSRRH CDU DISPLAY LOCS (RH)
BCD CHARACTERS
CDU DISPLAY LOC's
RH DISPLAY
CDPNL2
HERE WHEN DATA SEL SW
IS NOT ON MODE/BITE
CDCM4
SYMOD & X'0080
= 0
= 1 (PRESS-TO-TEST)
CDCM5
MSRLH = X'C888
LSRLH = X'8800
MSRRH = X'C888
LSRRH = X'8880
STDSP+ = STDSP– & X'03FF + X'FC00
CDPNL2

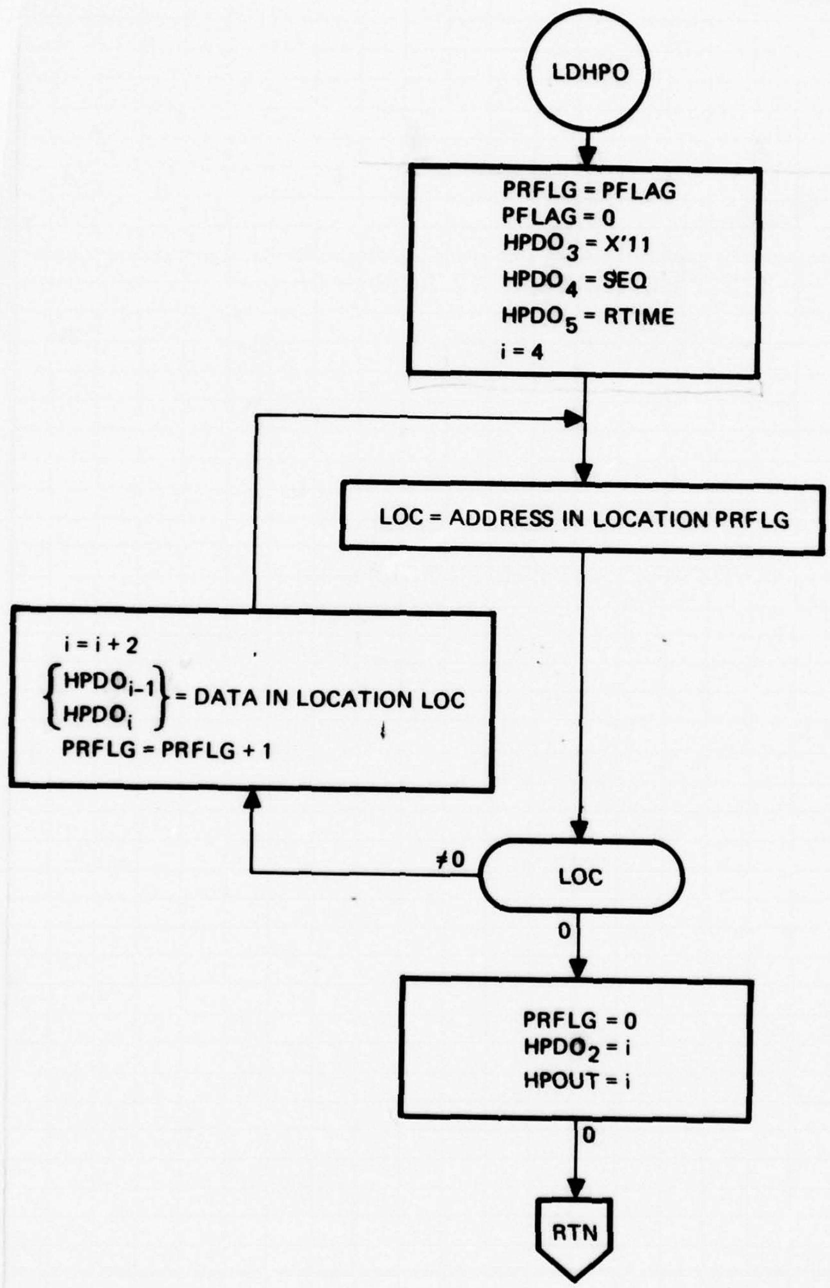

CDCM5
HERE WHEN DATA SEL SW IS NOT ON MODE/BITE, AND PRESS-TO-TEST IS FALSE
SYMOD & X'0007 (DATA SEL SW)
LAT LONG
(0)
(1)
GS HDG
V.VEL ALT
(2)
(3)
N/S VEL E/W VEL
(4)
PITCH ROLL
MODF
(= 0)
(≠ 0)
D1 = LAT
D2 = LON
D1 = SMCS2
D1 = VZ
D2 = ALTD
D1 = DMDD1
D2 = DMDD2
D1 = PITCH
D2 = RφLL
D1 = SMCS1
D1 = VG
D2 = HDGD
D1 = SGAP1
D2 = SGAP2
D1 = VN
D2 = VE
BCD
CONVERT D1, D2 OCTAL TO BCD FOR DISPLAY
STORE D1 - BDC IN MSRLH, LSRLH
STORE D2 - BCD IN MSRRH, LSRRH
CDPNL2
(0000/0010) OFF STBY
SYMOD&X'0030 (SYSTEM MODE SW)
(0030) NAV
ALIGN (0020)
A = 0
A = SHGC
A = 3
MODCN = MODE
MODC+ = A
CDENT


CDENT
(ENTER FLAG SET
IN INOUT ROUTINE)
= 0
ENTER
≠ 0
0
ENTER & X'0007
3,4,6,7
1
2
5
(+/-)
MSRIN
(SIGN DIGIT)
E/W
X2 = ALT
N/S
X2 = LATC
X2 = LONC
(OTHER)
MSRIN
(SIGN DIGIT)
MSRIN
(SIGN DIGIT)
+/-
+
N S E W
N
N
X2 = HDG
OCTCV
CONVERT MSRIN,
LSRIN TO OCTAL
KBN
KBW
KBS
KBE
STORE PER X2
N
ENTER = 0
= 0
STNV
≠ 0
NVCL
= 0
≠ 0
NVCL
= 0
CINTL
≠ 0
RSET1
RTN
RSET1


KBN
OCTCV
CONVERT BCD,
GET N_i
N_i - 12
(+)
(-/0)
IF N_i = 0, NVCL = 0
IF N_i = 1, NVCL = -
IF N_i = 2, SHGC = 1
IF N_i = 3, SHGC = 2
IF N_i = 4, TCG = RTIME
IF N_i = 5, DCG = LGAIN
IF N_i = 6, DCG = HGAIN
IF N_i = 7, ISWD = 0
IF N_i = 8, ISWD = 1
IF N_i = 9, ISWD = 2
IF N_i = 10, ISWD = 3
IF N_i = 11, PSPIN = 0
IF N_i = 12, PSPIN = 1
KBS
MODC
≠0
= 0
DTEMP = MSRIN X 2^7 & X'8000
OCTCV
CONVERT BCD
GET S_i
S_i
= 0
≠0
A = X'8000
S_i - 19
+
(-/0)
S_i - 15
(-)
(+/0)
A = S_i + DTEMP
A = S_i
TCI = A
STDSP$^+$ = STDSP$^-$ & X'03FF + X'8000
KBE
OCTCV
CONVERT BCD
GET E_i
PDFLG = E_i + X'8000
RTN
RNT
KBW
CONVERT
BCD TO HEX
GET W_i
WDNO = W_i (ADRESS)
BDFLG = "-"



PLSTQ
PRINH
= 0
≠0
PDFLG
-
+/0
PFLAG
≠0
= 0
PDFLG&X'0007
(A = ALIST$_i$)
PDFLG = +
PRFLG
≠0
= 0
RTIME - PTIME
-
+
PTIME = RTIME + DPTIM
A = ALIST$_i$
PFLAG = Adr. of ALIST$_i$
PRINH
(+)
(-)
HPOUT$^+$ = HPOUT$^-$ @ X'8000
HPOUT$^+$&X'7FFF
≠0
= 0
PFLAG
≠ 0
= 0
LDHPO
HPOUT$^+$ = HPOUT$^+$ & X'7FFF
RTN


LDHPO
PRFLG = PFLAG
PFLAG = 0
HPDO3 = X'11
HPDO4 = SEQ
HPDO5 = RTIME
i = 4
LOC = ADDRESS IN LOCATION PRFLG
i = i + 2
HPDOi-1
HPDOi
= DATA IN LOCATION LOC
PRFLG = PRFLG + 1
≠0
LOC
0
PRFLG = 0
HPDO2 = i
HPOUT = i
0
RTN

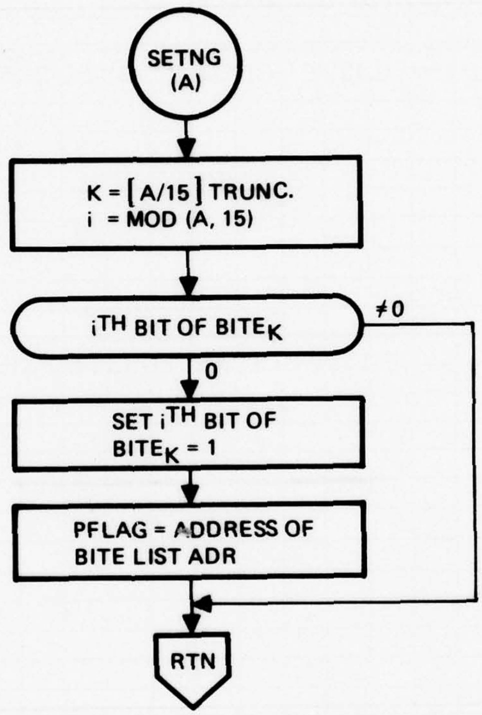

SETNG
(A)
K = [A/15] TRUNC.
i = MOD (A, 15)
iTH BIT OF BITEK
≠0
0
SET iTH BIT OF
BITEK = 1
PFLAG = ADDRESS OF
BITE LIST ADR
RTN

TABLE H-1. BITE CONSTANTS

SYMBOL	DEFINITION	VALUE	MAX VALUE	SCALED VALUE
$KMUX_1$	SEU Delta Overtemp Limit	30^{o}F	312.5^{o}F	0.096
$KMUX_2$	C/A, EMA Delta Overtemp Limit	30^{o}F	312.5^{o}F	0.096
KINT	Uncontrolled Internal Temp	50^{o}F	312.5^{o}F	0.16
	Delta Overtemp Limits			
KAIR	Inlet Air Delta Overtemp Limit	50^{o}F	312.5^{o}F	0.16
KBAT	Battery Delta Overtemp Limit	50^{o}F	312.5^{o}F	0.16
DVG	Accelerometer Reasonableness Reference	$\left(\frac{32.174}{8}\right)^2$ fps^2	2^{14} fps^2	9.8721^{-4}
DVBIT	Accelerometer Reasonableness Threshold	(.068)DVG	2^{14} fps^2	2^{-13}
VGMX	Max Velocity Threshold	2^{11} fps	2^{12} fps	2^{-1}
OBDT1	System-on-Battery Drain Per $\frac{1}{8}$ sec $\left(\begin{matrix}\text{Subr.}\\ \text{Therm}\end{matrix}\right)$	$\left(\frac{10.5}{8}\right)$ amp-sec	130	0.0101
OBDT2	28 VDC Backup Drain Per Second	0.5 amp-sec	130	0.00385
GOT	Rotor Delta Overtemp Limit	2 μin.	167 μin.	0.0120
GAPT2	Unsafe Gap Tolerance	15 μin.	167 μin.	0.0898
GMO	Mum Magnitude Reference	0.9	1	0.9
DGM	Mum Magnitude Threshold	0.05	1	0.05
ORTH	Spin Orthogonality Threshold	Sin 15^{o}	1	2^{-2}
DFR	Demod Frequency Threshold	10 Hz	1302.08 Hz	0.00768
ENBIT	IAU Rotation Motor BITE Threshold	0.08^{o}	π rad	0.000444
KSMCS	Gyro Delta Overtemp Limit	30^{o}F	521^{o}F	.0576
PVPV	Temp Monitor Reference Voltage Scale Factor	-.45033	1	-.45033

TABLE H-2. BACKGROUND VARIABLES

SYMBOL	INDEX i	INDEX j	DEFINITION	MAX VALUE	WORD LENGTH
NVCL	–	–	CAL/Nav Mode Switch Command	–	16
SMRF	–	–	Smoothed Temp. Mon. Ref. Volts	6.6666V.	16
DVR	–	–	Temp. Mon. Ref. Volts. Correction	5. V.	16
SYNFL	–	–	Synchro Initialization Check Sequencer	–	16
VG	–	–	Ground Speed (Nav)	2500 fps	16
SDOT	–	–	$SN_1 \cdot SN_2$ (Nav)	1	32
MODC	–	–	Mode Command from CDU	–	16
MODF	–	–	Functioning Mode	–	16
PRINH	–	–	HP-or-Printer Interface Flag (-=HP, +=Printer, 0=Neither or Instrumentation.)	–	16
PFLAG	–	–	Print Flag	–	16
PRFLG	–	–	Buffered PFLAG	–	16
PTIME	–	–	Print Time	–	16
ALIST	–	–	Address of Print LIst	–	16
DPTIME	–	–	Print Time Interval	–	16
$HPDI_i$,$HPDO_i$	1,...,63	–	HP Input & Output Buffers	–	16
GSWD	–	–	Gyro Status Word	–	16
STDSP	–	–	Display Status Word	–	16
$BITE_i$	1,...,8	–	BITE Flags	–	16
LSRIN, MSRIN	–	–	Least and Most Significant CDU Input Registers	–	16
ENTER	–	–	Keyboard Entry Flag	–	16
ROTC	–	–	Time of Last Rotator Turnaround	2^{15} Cycles	16
ENP	–	–	Previous Value of EN (1 Sec old)	π rad	16
SIMFL	–	–	Simulator Flag: IF SIMFL$\neq$0, Simulate	–	16
$DMOD_i$	1,2		Demod Ref. Frequency	1302.08 Hz	16
HZC_i	1,2		Rotor Speed	1302.08 Hz	16
SYMOD	–	–	CDU Input Mode Word	–	16
$ATMG_i$	1,2		Gyro Temp Point Set	521°F	16
$ATMS_i$	–	–	SEU Temp Set Point	312°F	16
ATME	–	–	EMA Temp Set Point	312°F	16
$ATMC_i$	1,2	–	Charge Amp Temp Set Point	312°F	16

TABLE H-3. BUILT-IN TESTS

Bite No.	Word/ Bit	Condition	Tested In Mode	Tested In Subroutine	Action
1	1/15	Fast cycle *incomplete* at *next* PIR1 interrupt	All	PIR1 Interrupt	Continue
2	1/14	SPARE			
3	1/13	System parallel I/O busy (STO1 = 1) (Lab only)	All	FST64 & Int. Timer	Continue
4	1/12	Failed to read HPFLG from HP2100 (Lab only)	All	Inout	Continue
5	1/11	Unrecognized input data code from HP2100 (Lab only)	All	Background	Continue
6	1/10	DPU I/O test word failure	All	FASTC	Continue
7	1/9	Excessive Rotor Excursion (Biomation trigger)	–	PIRO interrupt	Desuspend & Shutdown
8	1/8	Suspended at entry to system checks, Z heat, or suspend modes	Start	TCI′ = 1, 2, 3	Abort mode to idle
9	1/7	Not suspended at entry to suspended heat mode	Start	TCI′ = 5	Abort mode to idle
10	1/6	No preload in Z-heat mode, or failure to suspend	Start	TCI′ = 2, 3	Abort mode to idle
11	1/5	EMA Counter: X ≠ Y	Start	*Charge Mon.*	*Continue*
12	1/4	EMA Counter: Y ≠ Z	Start	Charge Mon.	Continue
13	1/3	EMA Counter: Z ≠ 40 kHz	Start	Charge Mon.	Continue
14	1/2	SPARE			
15	1/1	APARE			
16	2/15	Mode time out: System checks (TCI′ = 1, Limit = 1805 sec)	Start	Start	Abort mode to idle
17	2/14	Mode time out: Z-Heat (TCI′ = 2, Limit = 3.5 min)	Start	Start	Abort mode to idle
18	2/13	Mode time out: Suspend (TCI′ = 3, Limit 120 sec)	Start	Start	Abort mode to idle
19	2/12	Mode time out: Charge monitor (TCI′ = 4, Limit = 3 sec)	Start	Start	Abort mode to idle
20	2/11	Mode time out: Suspended heat (TCI′ = 5, Limit = 40 sec)	Start	Start	Abort mode to idle
21	2/10	Mode time out: Low Freq. Degauss (TCI′ = 6, Limit = 3 sec)	Start	Start	Abort mode to idle
22	2/9	*Mode time out: Spin Gyro No. 1* (TCI′ = 7, Limit = 15 sec)	Start	Start	Abort mode to idle
23	2/8	Mode time out: Damp Gyro No. 1 (TCI′ = 8, Limit = 60 sec)	Start	Start	Abort mode to idle
24	2/7	Mode time out: (not assigned) (TCI′ = 9, Limit = 15 sec)	Start	Start	Abort mode to idle
25	2/6	Mode time out: Spin Gyro No. 2 (TCI′ = 10, Limit = 15 sec)	Start	Start	Abort mode to idle
26	2/5	Mode time out: Damp Gyro No. 2 (TCI′ = 11, Limit = 60 sec)	Start	Start	Abort mode to idle
27	2/4	*Mode time out: (not assigned)* (TCI′ = 12, *Limit* = 15 sec)	Start	Start	Abort mode to idle
28	2/3	Mode time out: Temp stabilization (TCI′ = 13, Limit = 5 min)	Start	Start	Abort mode to idle
29	2/2	Mode time out: High freq Degauss (TCI′ = 14, Limit = 3 sec)	Start	Start	Abort mode to idle
30	2/1	Mode time out: Standby (TCI′ = 15, Limit = 3 sec)	Start	Start	Abort mode to idle

TABLE H-3. (Cont)

Bite No.	Word/ Bite	Condition	Tested In Mode	Tested In Subroutine	Action
31	3/15	Gyro No. 1 rotor speed exceeds tolerance (DEMOD freq ±10 Hz)	Nav	Nav bkgnd	Continue
32	3/14	Gyro No. 2 rotor speed exceeds tolerance (DEMOD freq ±10 Hz)	Nav	Nav bkgnd	Continue
33	3/13	Gyro No. 1 rotor positioning error exceeds 6 deg	Start	Standby	Continue
34	3/12	Gyro No. 2 rotor positioning error exceeds 6 deg	Start	Standby	Continue
35	3/11	Redundant axis changing **BITE**	Nav	**SPTNV**	**Continue**
36	3/10	Align north gyro drift bias estimate exceeds .07 deg/hr	Align	Align	**If in START, desuspend**
37	3/9	Gyro No. 1 exceeds large charge threshold			**& resuspend.**
38	3/8	Gyro No. 2 exceeds large charge threshold	Start	Chg mon.	**After 6 failures shutdown.**
39	3/7	Gyro No. 1 exceeds small charge threshold Temporarily	&	&	**If in NAV, shutdown.**
40	3/6	Gyro No. 2 exceeds small charge threshold disabled	Nav	Cg	
41	3/5	Gyro No. 1 DEMOD phase lock lost	All	DEMOD	Continue
42	3/4	Gyro No. 2 DEMOD phase lock lost	All	DEMOD	Continue
43	3/3	SPARE			
44	3/2	SPARE			
45	3/1	APARE			
46	4/15				
47	4/14				
48	4/13				
49	4/12				
50	4/11				
51	4/10	Reserved for system checks mode (TCI′ = 1)			
52	4/9	**BITE's at power turn-on.**			
53	4/8	Not presently implemented.			
54	4/7				
55	4/6				
56	4/5				
57	4/4				
58	4/3	Battery overtemp during fast charge	Start	TCI′ = 1	Delay 1 min, then shutdown.
59	4/2	Battery test failed	Start	TCI′ = 1	30 min battery charge, then **abort to idle.**
60	4/1	Battery Drain failure	All	Background	Shutdown

TABLE H-3. (Cont)

Bite No.	Word/ Bit	Condition		Tested In Mode	Subroutine	Action
61	5/15	SPARE				
62	5/14	-24 V reg pwr supply exceeds tolerance	(±3.6 V)	All	Background	
63	5/13	-15 V reg (Crit) pwr supply exceeds tolerance	(±2.25 V)	All	Background	
64	5/12	-15 V unreg pwr supply exceeds tolerance	(±6.0 V)	All	Background	
65	5/11	+7.5 V reg pwr supply exceeds tolerance	(±1.125 V)	All	Background	
66	5/10	-7.5 V reg pwr supply exceeds tolerance	(±1.125 V)	All	Background	
67	5/9	+5.2 V reg (C) pwr supply exceeds tolerance	(±0.78 V)	All	Background	Set Bite and shutdown if tolerance is exceeded on 5 consecutive samples
68	5/8	+12 V reg pwr supply exceeds tolerance	(±1.8 V)	All	Background	
69	5/7	-12 V reg pwr supply exceeds tolerance	(±1.8 V)	All	Background	
70	5/6	+15 V reg (S) pwr supply exceeds tolerance	(±2.25 V)	All	Background	
71	5/5	-15 V reg (S) pwr supply exceeds tolerance	(±2.25 V)	All	Background	
72	5/4	+5 V ADC reference exceeds tolerance	(±2.0 V)	All	Background	
73	5/3	-5 V ADC reference exceeds tolerance	(±2.0 V)	All	Background	
74	5/2	Ground ADC reference exceeds tolerance	(±1.0 V)	All	Background	
75	5/1	Gyro No. 1 case delta overtemp	(30°F)	All	Background	
76	6/15	Gyro No. 1 rotor delta overtemp	(15 μ in.)	All	Background	
77	6/14	Charge Amp No. 1 delta overtemp	(30°F)	All	Background	
78	6/13	Charge Amp No. 2 delta overtemp	(30°F)	All	Background	
79	6/12	EMA block delta overtemp	(30°F)	All	Background	Set bite and shutdown if temperature is greater than set point plus tolerance on 5 consecutive samples
80	6/11	SEU No. 1 delta overtemp	(30°F)	All	Background	
81	6/10	SEU No. 2 delta overtemp	(30°F)	All	Background	
82	6/9	SEU No. 3 delta overtemp	(30°F)	All	Background	
83	6/8	Gyro No. 2 case delta overtemp	(30°F)	All	Background	
84	6/7	Gyro No. 2 rotor delta overtemp	(15 μ in.)	All	Background	
85	6/6	MUX No. 2 delta overtemp	(50°F)	All	Background	
86	6/5	Inlet air delta overtemp	(50°F)	All	Background	
87	6/4	Battery delta overtemp	(50°F)	All	Background	Set bite and continue if tolerance is exceeded on 5 consecutive samples
88	6/3	MUX No. 1 delta overtemp	(50°F)	All	Background	
89	6/2	Converter module delta overtemp	(50°F)	All	Background	
90	6/1	Gyro No. 1 GAP is greater than set point +2 μ in.		All	Background	

TABLE H-3. (Concluded)

Bite No.	Word/ Bit	Condition	Tested In		Action
			Mode	Subroutine	
91	7/15	Gyro No. 2 GAP is greater than set point +2 μ in.	All	Background	Same as Bite No. 85-90
92	7/14	External memory power supply out of tolerance	All	Background	Continue
93	7/13	Memory check sum failure	All	Background	Continue
94	7/12	SPARE			
95	7/11	SPARE			
96	7/10	EMA pulse rate $\neq$ 1 g	Align	Nav bkgnd	Continue
97	7/9	SPARE			
98	7/8	Velocity is greater than 2048 ft/sec	Nav	Nav bkgnd	Continue
99	7/7	Gyro No. 1 MUM magnitude exceeds tolerance (0.9 $\pm$ .05)	Nav	Nav bkgnd	Continue
100	7/6	Gyro No. 2 MUM Magnitude exceeds tolerance (0.9 $\pm$ .05)	Nav	Nav bkgnd	Continue
101	7/5	Spin vector non-orthogonality exceeds 15 deg	Nav	Nav bkgnd	Continue
102	7/4	SPARE	Nav	Nav bkgnd	Continue
103	7/3	SPARE			
104	7/2	Roll synchro output BITE	–	Nav bkgnd	
105	7/1	Pitch synchro output BITE — Temporarily	–	Nav bkgnd	
106	8/15	Heading synchro output BITE — disabled	–	Nav bkgnd	
107	8/14	DC analog output No. 1 BITE	–	Nav bkgnd	
108	8/13	DC analog output NO. 2 BITE	–	Nav bkgnd	
109	8/12	IAU rotator stopped moving	–	Nav bkgnd	Turn off rotator power, continue
110	8/11	28 vdc aircraft power loss	All	Background	Continue
111	8/10	400 Hz INU primary power loss, INU operating on battery	All	Background	Continue
112	8/9	Converter test: DI01 $\neq$ PDO05 — Temporarily	–	Background	
113	8/8	Converter test: DI02 $\neq$ PDO06 — Disabled	–	Background	
114	8/7	Converter test: DI03 $\neq$ PDO12	–	Background	
115	8/6	Noisy Roll converter data	–	Start bkgnd	
116	8/5	Noise pitch converter data	–	Start bkgnd	
117	8/4	Noisy heading converter data	–	Start bkgnd	
118	8/3	Synchro output Bad	–	Start bkgnd	
119	8/2	SPARE			
120	8/1	SPARE			

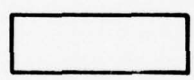
APPENDIX I

START PROGRAM

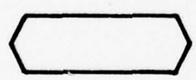
DETAILED FLOW CHARTS

FLOW CHART SYMBOLS

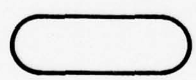
ENTRY POINT OR CONNECTOR



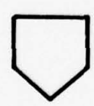
PROCESS



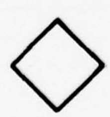
SUBROUTINE



BRANCH POINT



OFF-PAGE CONNECTOR

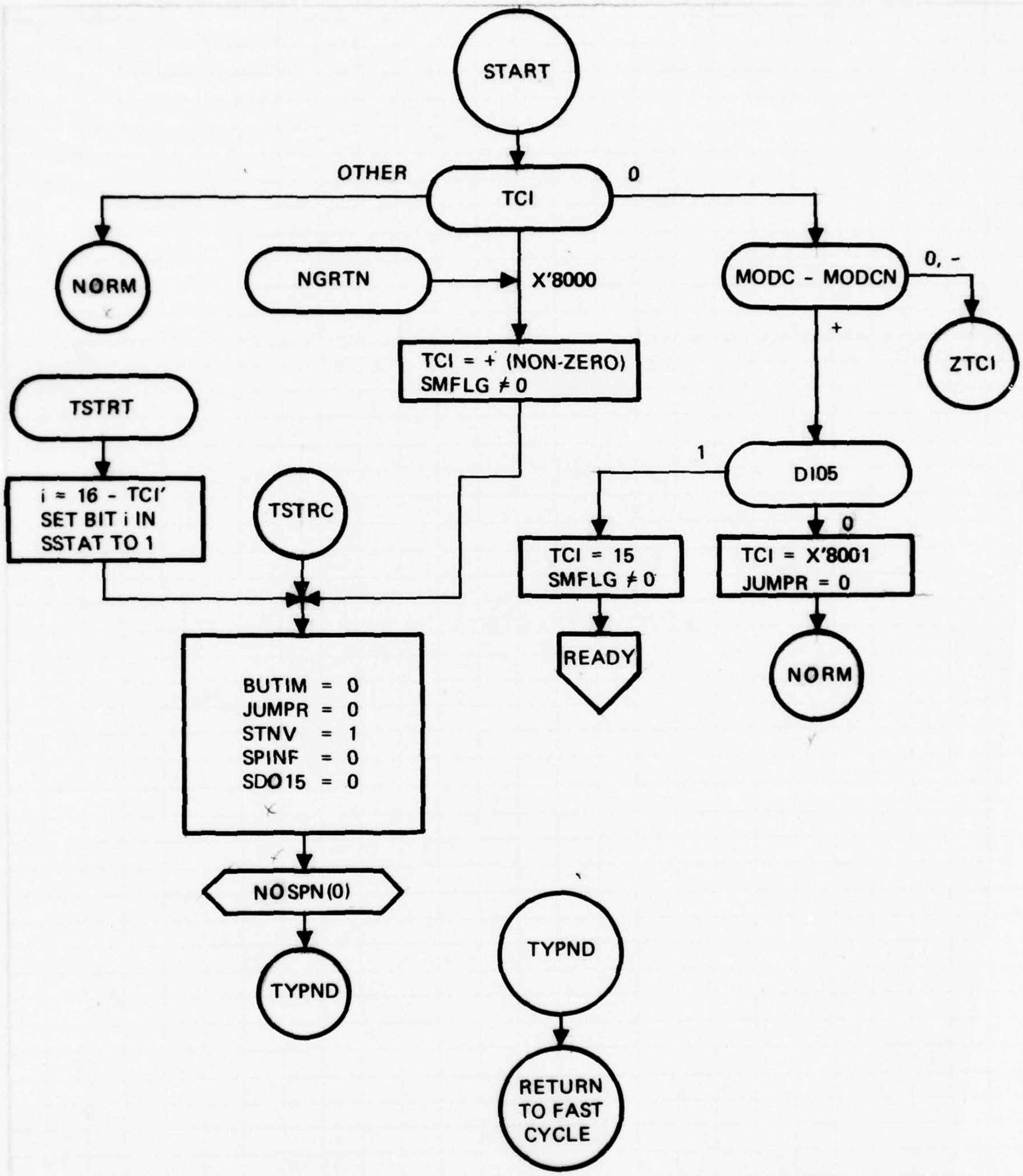


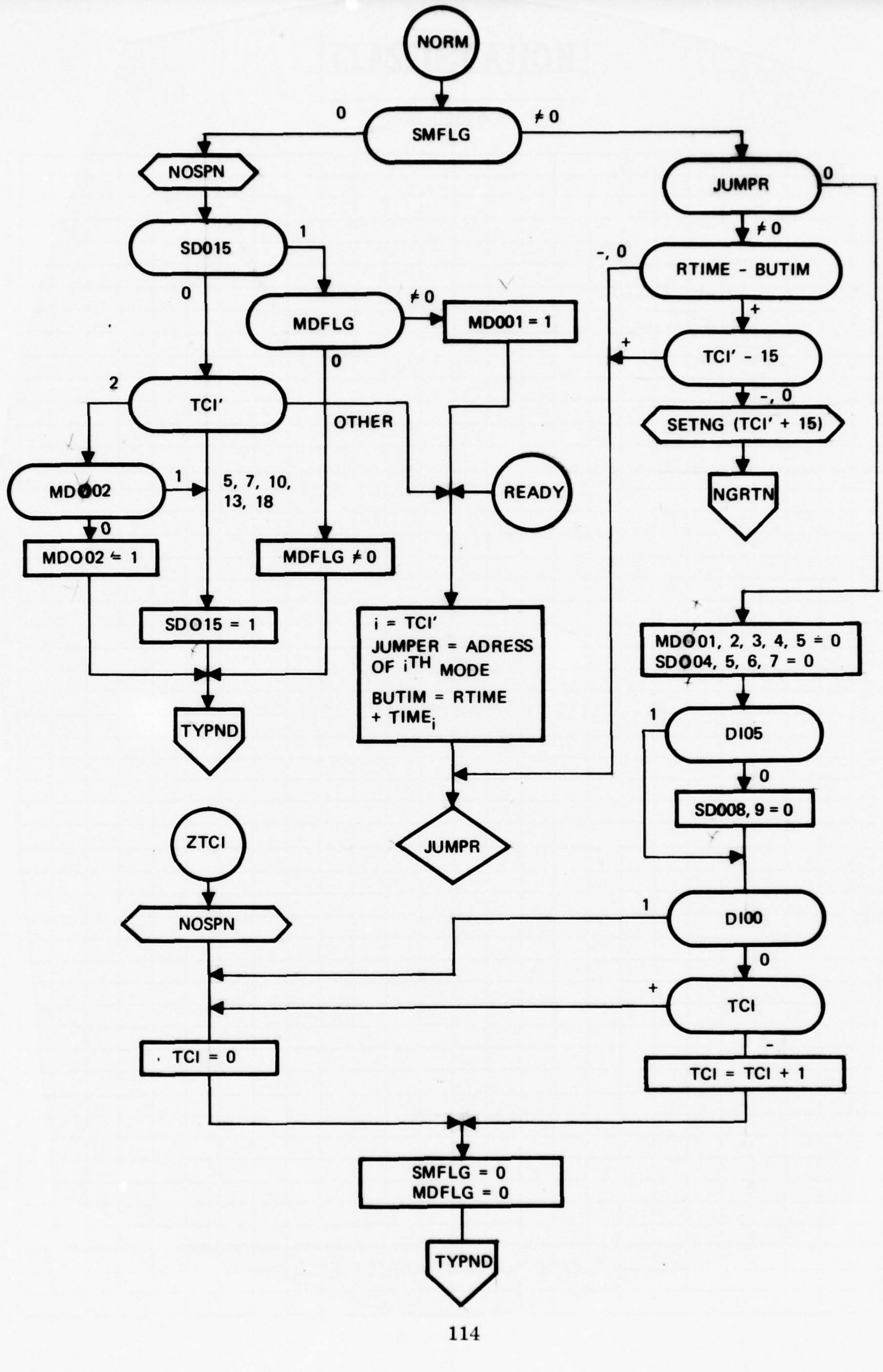
OFF-PAGE BRANCH

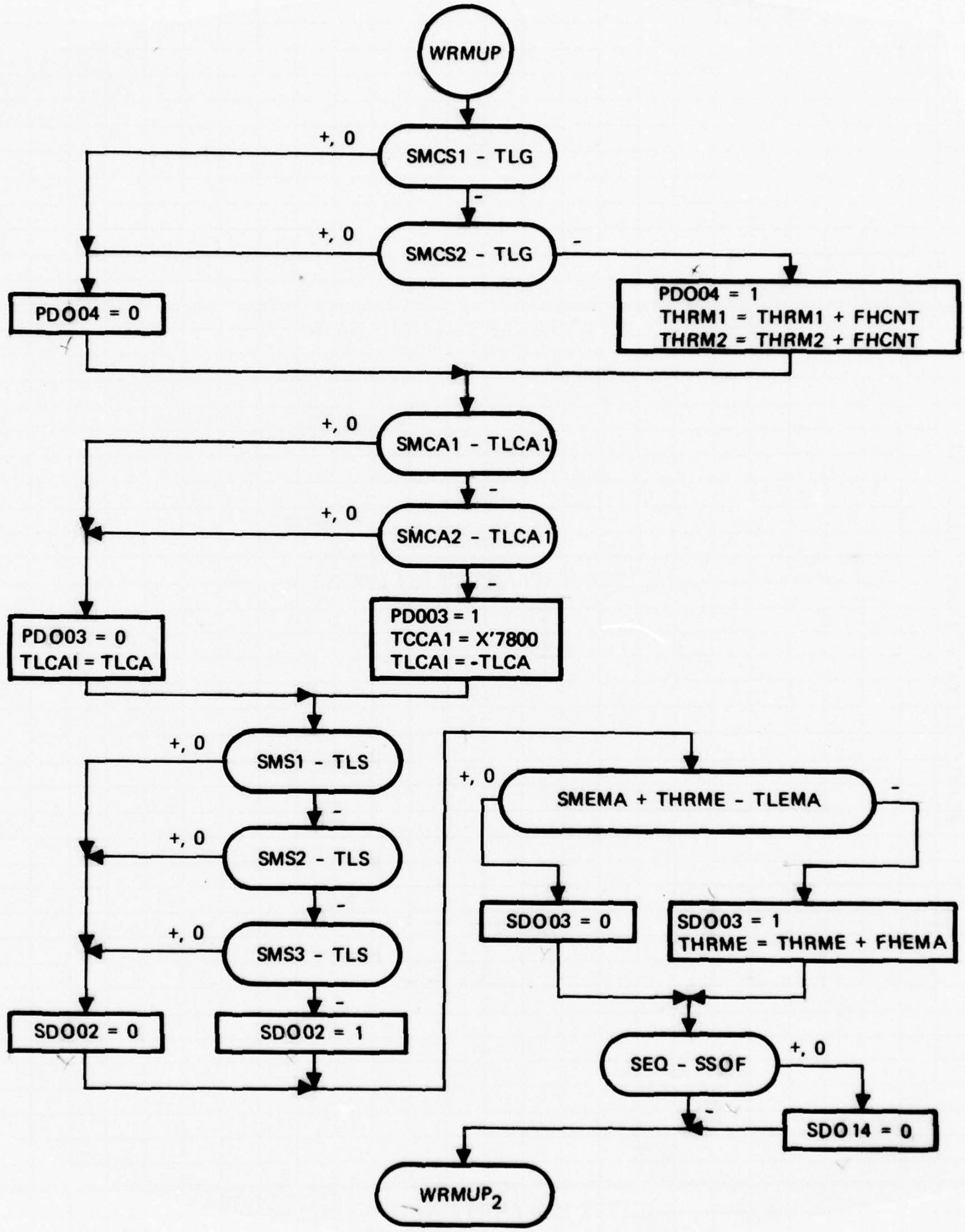
TABLE I-I. START PROGRAM MODES

TCI'	Mode	SD015 On	SD015 Off
0	Idle		X
1	System Checks		X
2	Heat	X	
3	Suspend		X
4	Charge Monitor		X
5	Suspended Z-Heat	X	
6	Low Frequency Degauss		X*
7	Spin 1	X	
8	Damp 1		X*
9	Final Spin 1 (NA)		
10	Spin 2	X	
11	Damp 2		X*
12	Final Spin 2 (NA)		
13	Temp Stab.	X	
14	High Frequency Degauss		X*
15	Standby		X
16	Manual Charge Mon		X
17	Desuspend		X
18	Manual Brake (NA)	X	
19	Spin Motor Offset Cal		

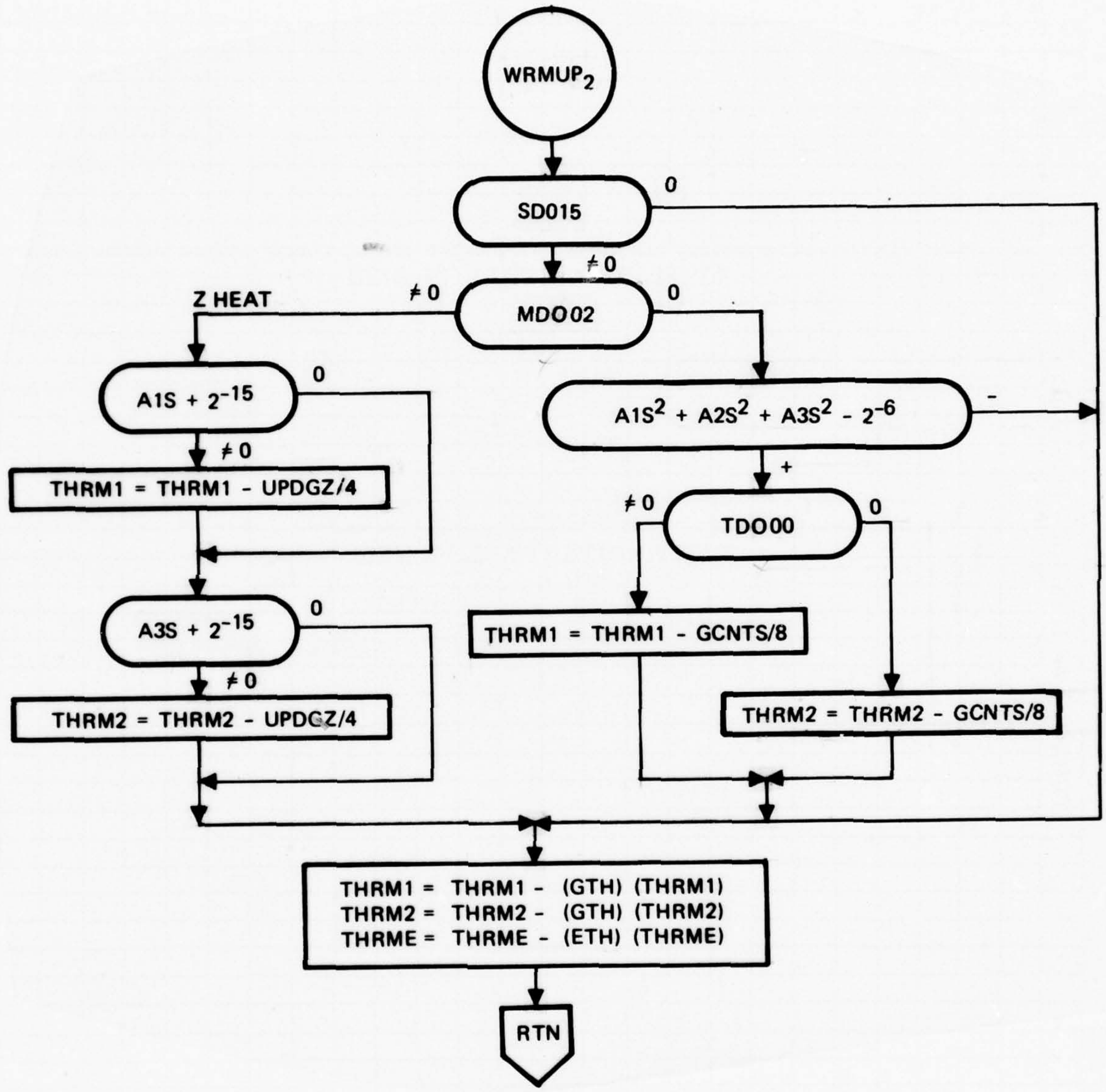
*For These Modes, SD015 is Initially Off and is Turned on During the Mode

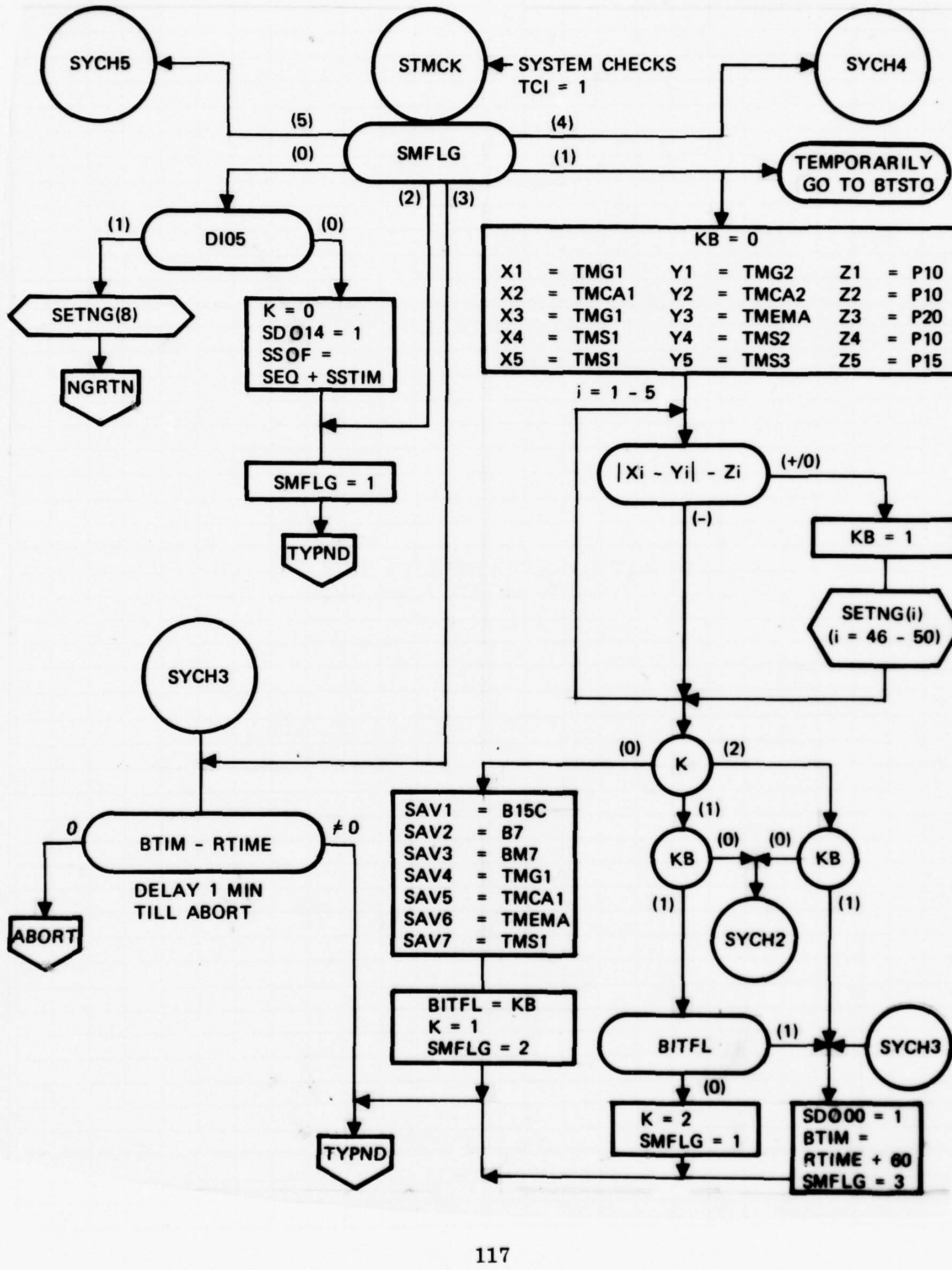

START
OTHER
TCI
0
NORM
NGRTN
X'8000
MODC - MODCN
0, -
+
ZTCI
TCI = + (NON-ZERO)
SMFLG ≠ 0
TSTRT
1
D105
i = 16 - TCI'
SET BIT i IN
SSTAT TO 1
TSTRC
0
TCI = 15
SMFLG ≠ 0
TCI = X'8001
JUMPR = 0
READY
NORM
BUTIM = 0
JUMPR = 0
STNV = 1
SPINF = 0
SDO15 = 0
NOSPN(0)
TYPND
TYPND
RETURN
TO FAST
CYCLE

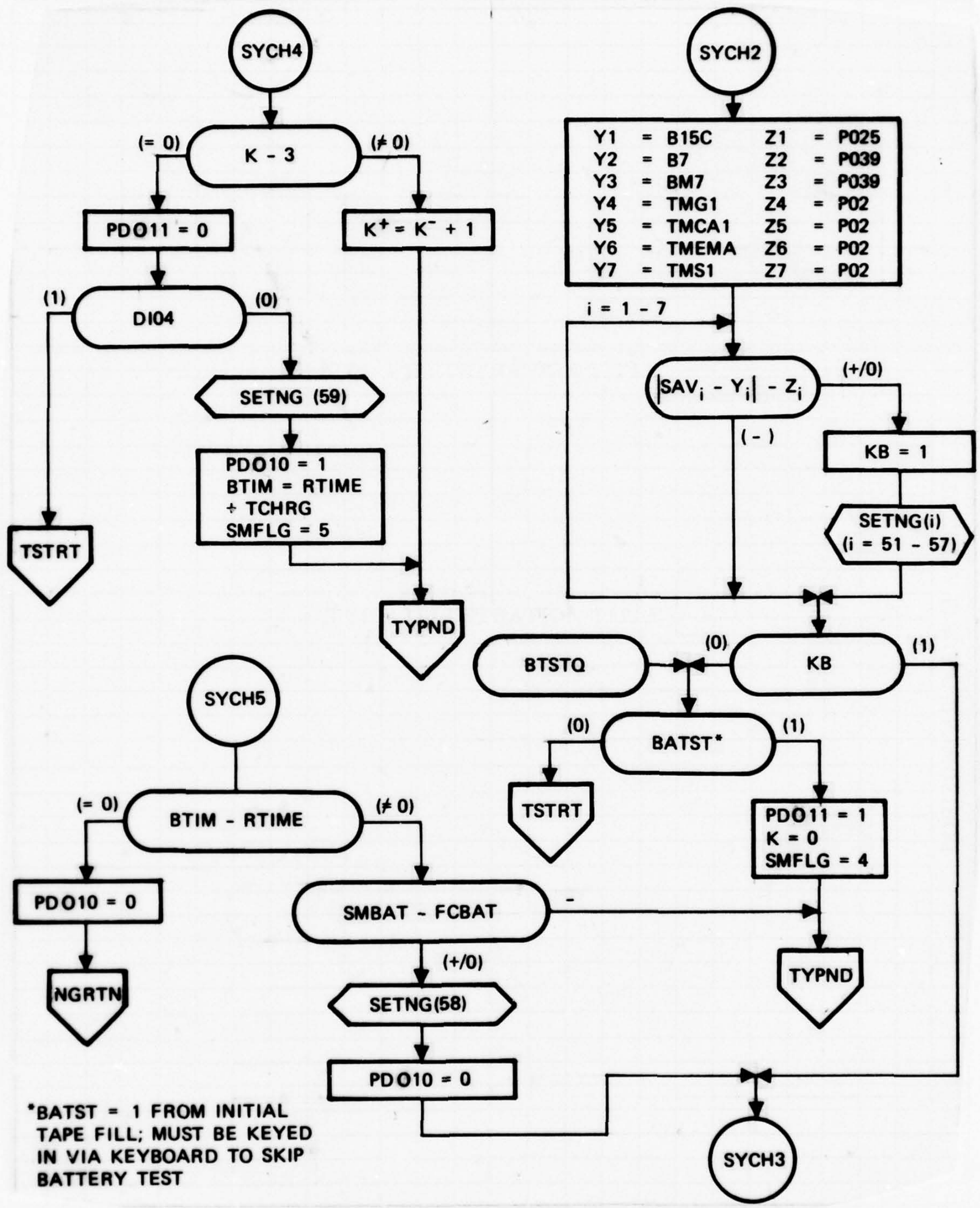

NORM
SMFLG
0
≠ 0
NOSPN
JUMPR
0
≠ 0
SD015
1
0
-, 0
RTIME - BUTIM
+
MDFLG
≠ 0
MD001 = 1
0
TCI' - 15
+
-, 0
2
TCI'
OTHER
SETNG (TCI' + 15)
NGRTN
MD002
1
5, 7, 10, 13, 18
READY
0
MDO02 = 1
MDFLG ≠ 0
SDO15 = 1
i = TCI'
JUMPER = ADRESS OF i^TH MODE
BUTIM = RTIME + TIME_i
MDO01, 2, 3, 4, 5 = 0
SDO04, 5, 6, 7 = 0
TYPND
DI05
1
0
SD008, 9 = 0
ZTCI
JUMPR
NOSPN
DI00
1
0
TCI
+
-
TCI = 0
TCI = TCI + 1
SMFLG = 0
MDFLG = 0
TYPND

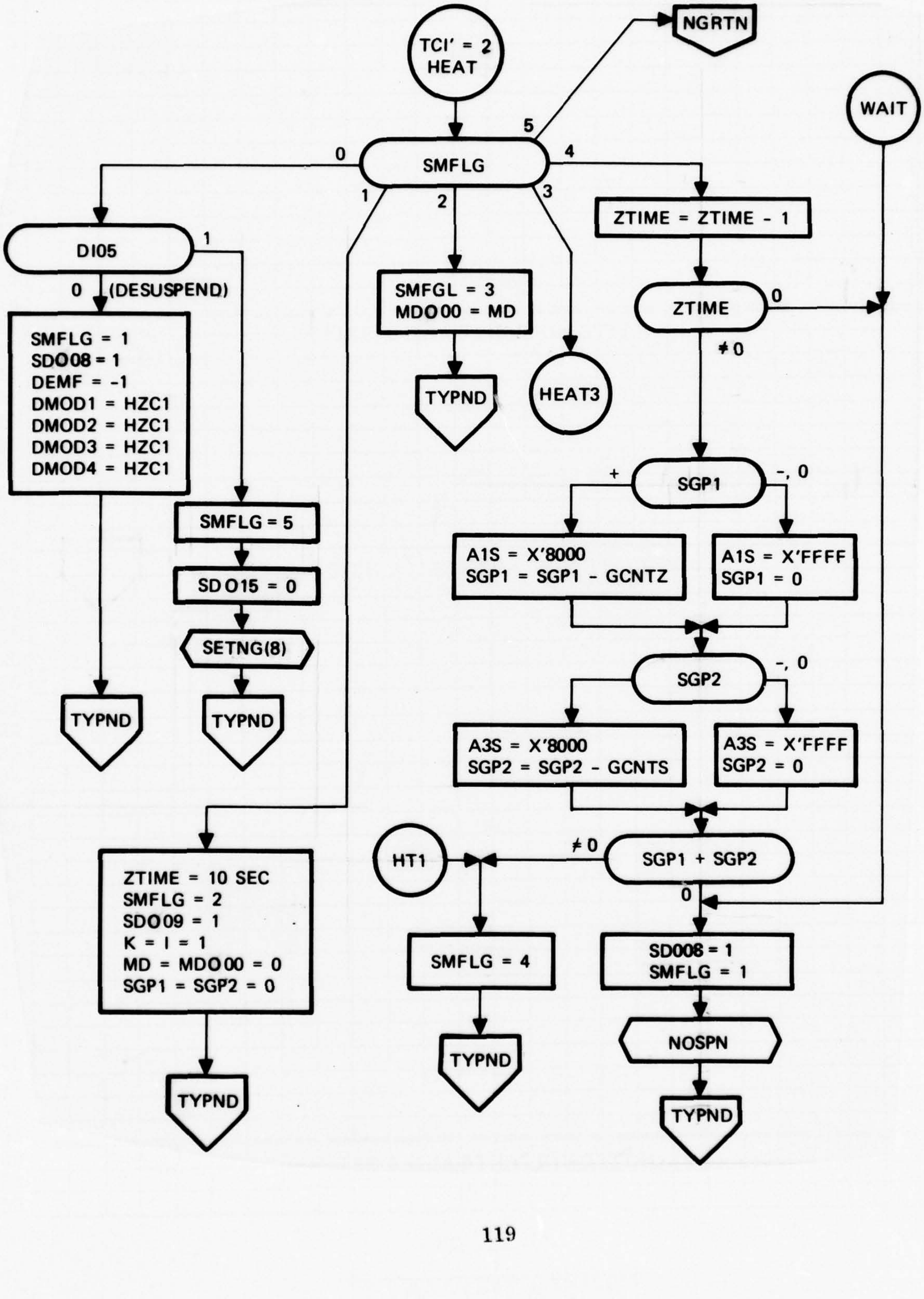


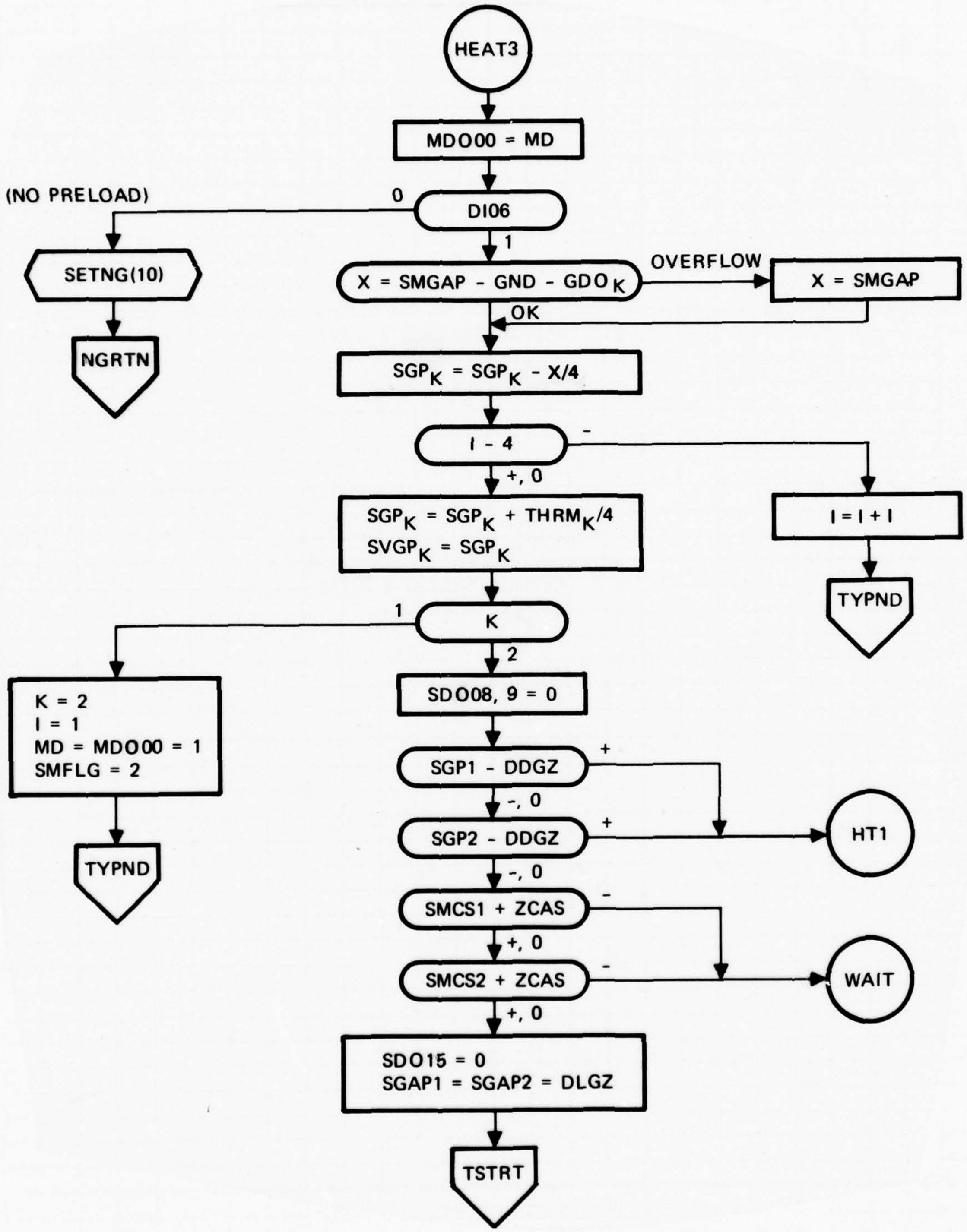
WRMUP
SMCS1 - TLG
+, 0
-
SMCS2 - TLG
+, 0
-
PDO04 = 0
PDO04 = 1
THRM1 = THRM1 + FHCNT
THRM2 = THRM2 + FHCNT
SMCA1 - TLCA1
+, 0
-
SMCA2 - TLCA1
+, 0
-
PDO03 = 0
TLCAI = TLCA
PD003 = 1
TCCA1 = X'7800
TLCAI = -TLCA
SMS1 - TLS
+, 0
-
SMS2 - TLS
+, 0
-
SMS3 - TLS
+, 0
-
SDO02 = 0
SDO02 = 1
SMEMA + THRME - TLEMA
+, 0
-
SDO03 = 0
SDO03 = 1
THRME = THRME + FHEMA
SEQ - SSOF
+, 0
-
SDO14 = 0
WRMUP2

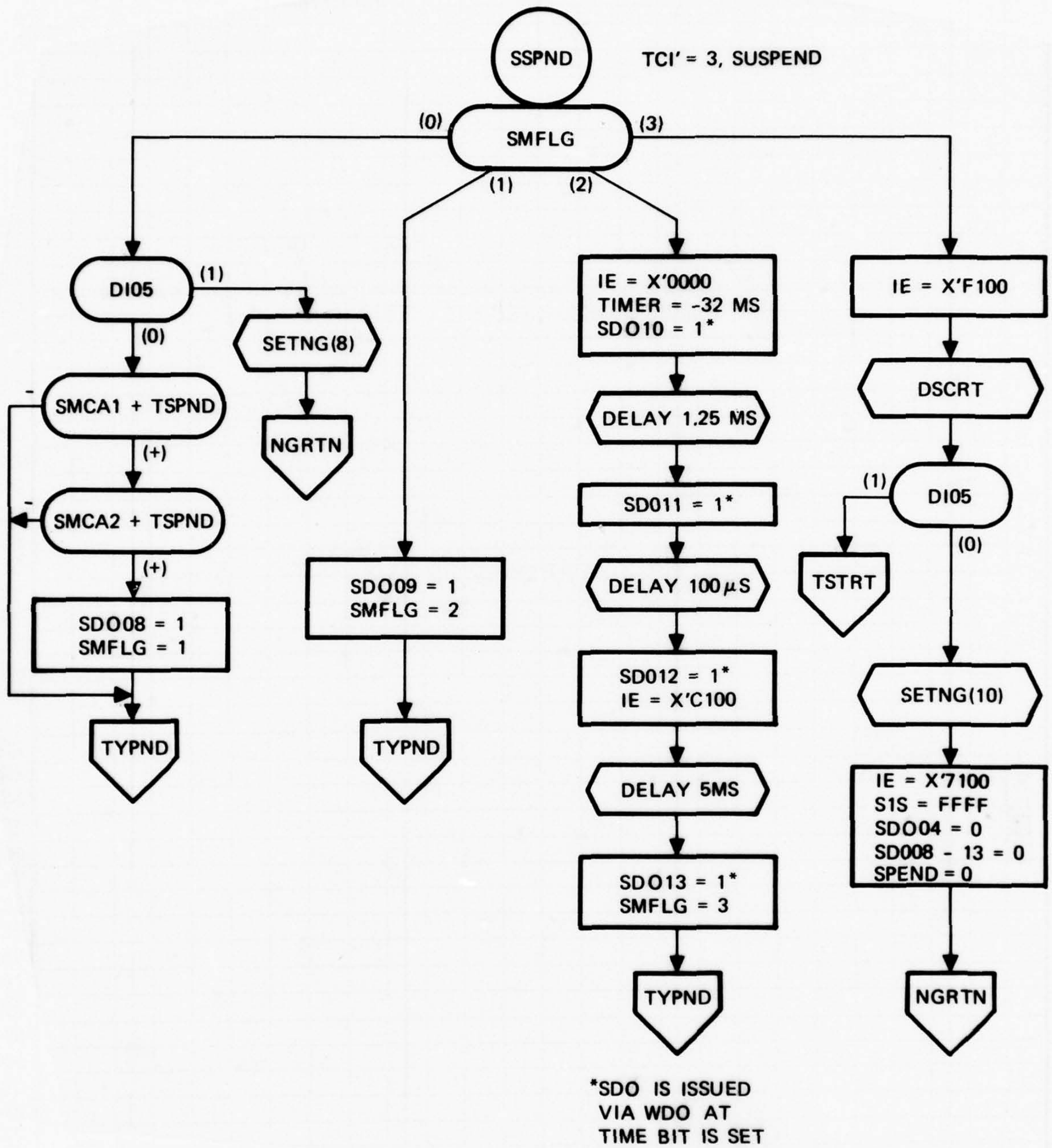

WRMUP2
SD015
0
≠0
Z HEAT
≠0
MDO02
0
A1S + 2-15
0
≠0
THRM1 = THRM1 - UPDGZ/4
A3S + 2-15
0
≠0
THRM2 = THRM2 - UPDGZ/4
A1S2 + A2S2 + A3S2 - 2-6
-
+
≠0
TDO00
0
THRM1 = THRM1 - GCNTS/8
THRM2 = THRM2 - GCNTS/8
THRM1 = THRM1 - (GTH) (THRM1)
THRM2 = THRM2 - (GTH) (THRM2)
THRME = THRME - (ETH) (THRME)
RTN


SYCH5
STMCK
SYSTEM CHECKS
TCI = 1
SYCH4
(5)
(4)
SMFLG
(0)
(1)
TEMPORARILY
GO TO BTSTQ
(2)
(3)
(1)
DI05
(0)
KB = 0
X1 = TMG1 Y1 = TMG2 Z1 = P10
X2 = TMCA1 Y2 = TMCA2 Z2 = P10
X3 = TMG1 Y3 = TMEMA Z3 = P20
X4 = TMS1 Y4 = TMS2 Z4 = P10
X5 = TMS1 Y5 = TMS3 Z5 = P15
SETNG(8)
K = 0
SDO14 = 1
SSOF =
SEQ + SSTIM
NGRTN
i = 1 - 5
SMFLG = 1
|Xi - Yi| - Zi
(+/0)
(-)
TYPND
KB = 1
SETNG(i)
(i = 46 - 50)
SYCH3
(0)
K
(2)
(1)
0
BTIM - RTIME
≠ 0
SAV1 = B15C
SAV2 = B7
SAV3 = BM7
SAV4 = TMG1
SAV5 = TMCA1
SAV6 = TMEMA
SAV7 = TMS1
KB
(0)
(0)
KB
DELAY 1 MIN
TILL ABORT
(1)
(1)
ABORT
SYCH2
BITFL = KB
K = 1
SMFLG = 2
BITFL
(1)
SYCH3
(0)
K = 2
SMFLG = 1
SDO00 = 1
BTIM =
RTIME + 60
SMFLG = 3
TYPND

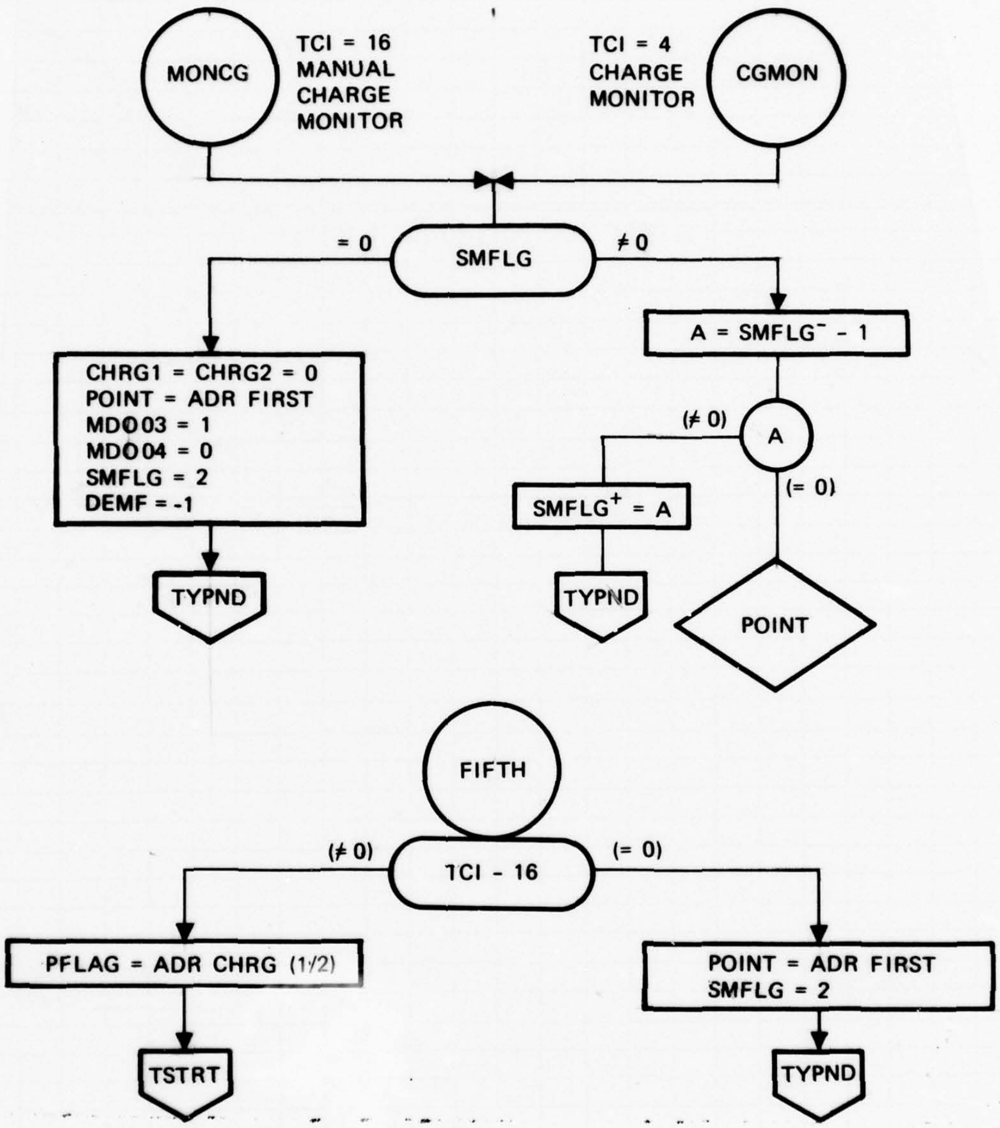

SYCH4
(= 0)
K - 3
(≠ 0)
PDO11 = 0
K+ = K- + 1
(1)
DI04
(0)
SETNG (59)
PDO10 = 1
BTIM = RTIME
+ TCHRG
SMFLG = 5
TSTRT
TYPND
SYCH2
Y1 = B15C Z1 = P025
Y2 = B7 Z2 = P039
Y3 = BM7 Z3 = P039
Y4 = TMG1 Z4 = P02
Y5 = TMCA1 Z5 = P02
Y6 = TMEMA Z6 = P02
Y7 = TMS1 Z7 = P02
i = 1 - 7
|SAVi - Yi| - Zi
(+/0)
(-)
KB = 1
SETNG(i)
(i = 51 - 57)
BTSTQ
(0)
KB
(1)
(0)
BATST*
(1)
TSTRT
PDO11 = 1
K = 0
SMFLG = 4
SYCH5
(= 0)
BTIM - RTIME
(≠ 0)
PDO10 = 0
SMBAT - FCBAT
-
NGRTN
(+/0)
SETNG(58)
TYPND
PDO10 = 0
*BATST = 1 FROM INITIAL
TAPE FILL; MUST BE KEYED
IN VIA KEYBOARD TO SKIP
BATTERY TEST
SYCH3

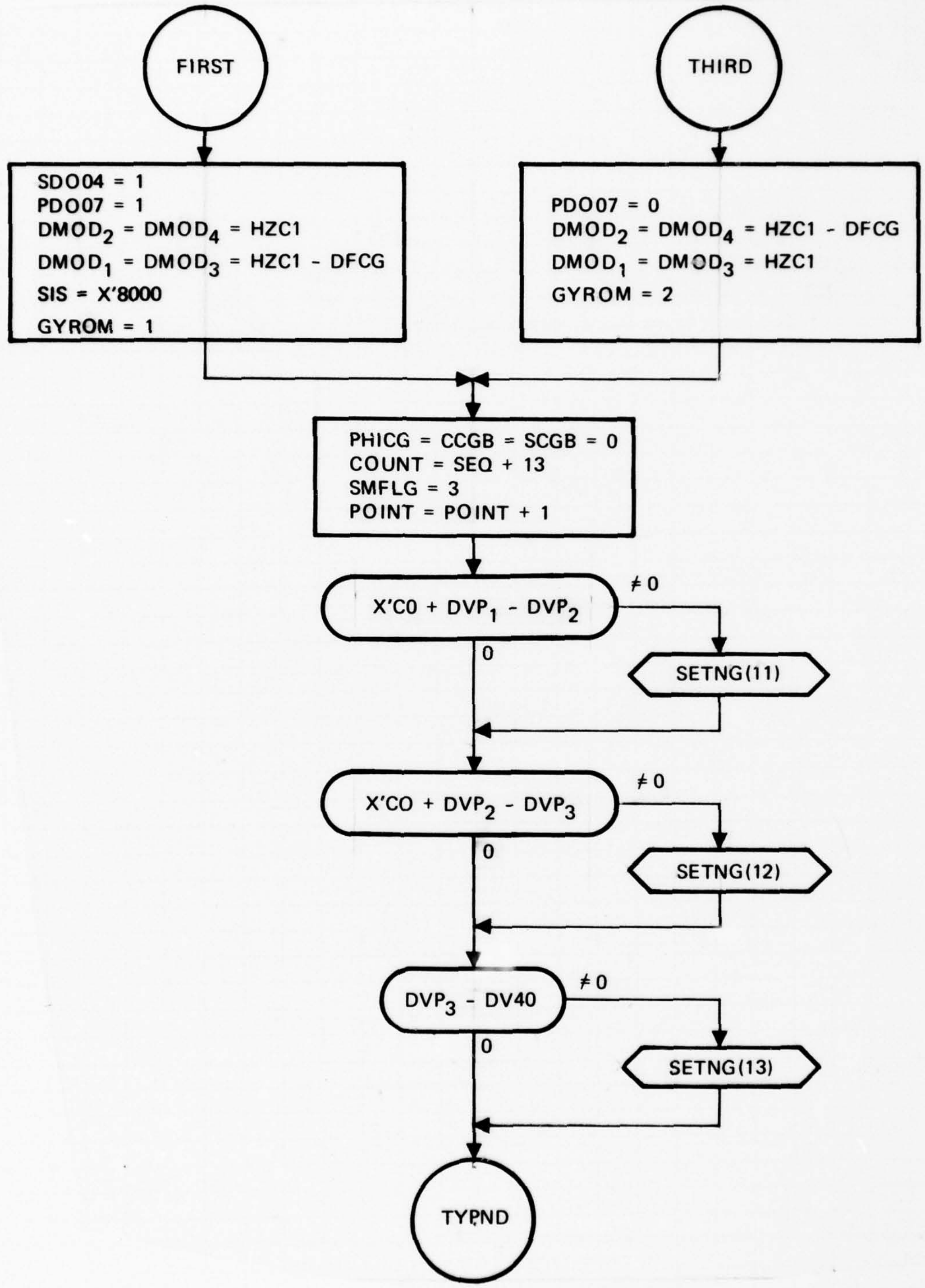

TCI' = 2
HEAT
NGRTN
WAIT
SMFLG
0
1
2
3
4
5
DI05
(DESUSPEND)
SMFLG = 1
SDO08 = 1
DEMF = -1
DMOD1 = HZC1
DMOD2 = HZC1
DMOD3 = HZC1
DMOD4 = HZC1
TYPND
SMFLG = 5
SD O15 = 0
SETNG(8)
TYPND
SMFGL = 3
MDO00 = MD
TYPND
HEAT3
ZTIME = ZTIME - 1
ZTIME
≠0
SGP1
+
-, 0
A1S = X'8000
SGP1 = SGP1 - GCNTZ
A1S = X'FFFF
SGP1 = 0
SGP2
-, 0
A3S = X'8000
SGP2 = SGP2 - GCNTS
A3S = X'FFFF
SGP2 = 0
ZTIME = 10 SEC
SMFLG = 2
SDO09 = 1
K = I = 1
MD = MDO00 = 0
SGP1 = SGP2 = 0
TYPND
HT1
≠0
SGP1 + SGP2
SMFLG = 4
TYPND
SD008 = 1
SMFLG = 1
NOSPN
TYPND

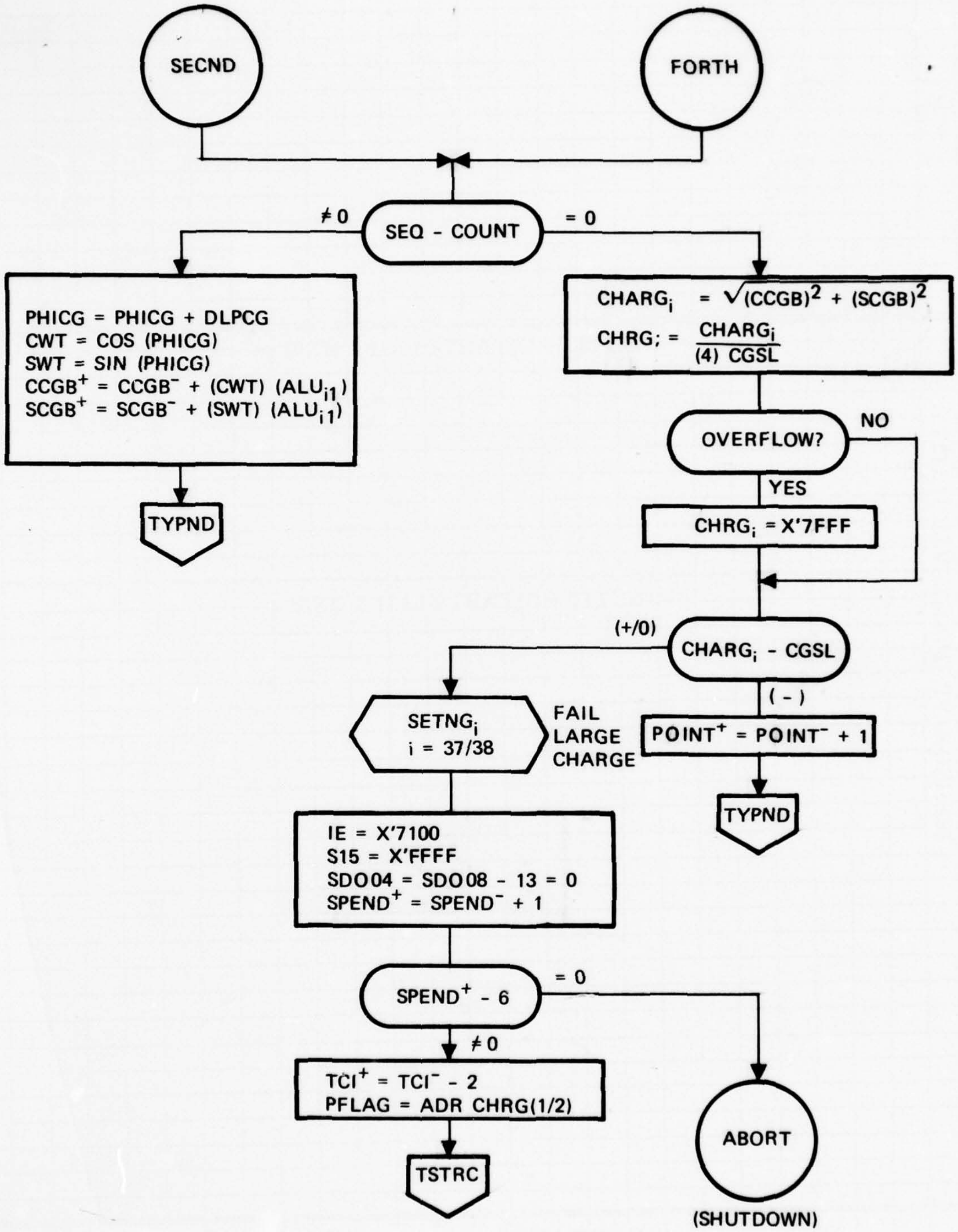

HEAT3
MDO00 = MD
(NO PRELOAD)
0
D106
1
SETNG(10)
NGRTN
X = SMGAP - GND - GDO K
OVERFLOW
X = SMGAP
OK
SGP K = SGP K - X/4
I - 4
-
+, 0
SGP K = SGP K + THRM K /4
SVGP K = SGP K
I = I + I
TYPND
1
K
2
K = 2
I = 1
MD = MDO00 = 1
SMFLG = 2
TYPND
SDO08, 9 = 0
SGP1 - DDGZ
+
-, 0
SGP2 - DDGZ
+
HT1
-, 0
SMCS1 + ZCAS
-
+, 0
SMCS2 + ZCAS
-
WAIT
+, 0
SDO15 = 0
SGAP1 = SGAP2 = DLGZ
TSTRT

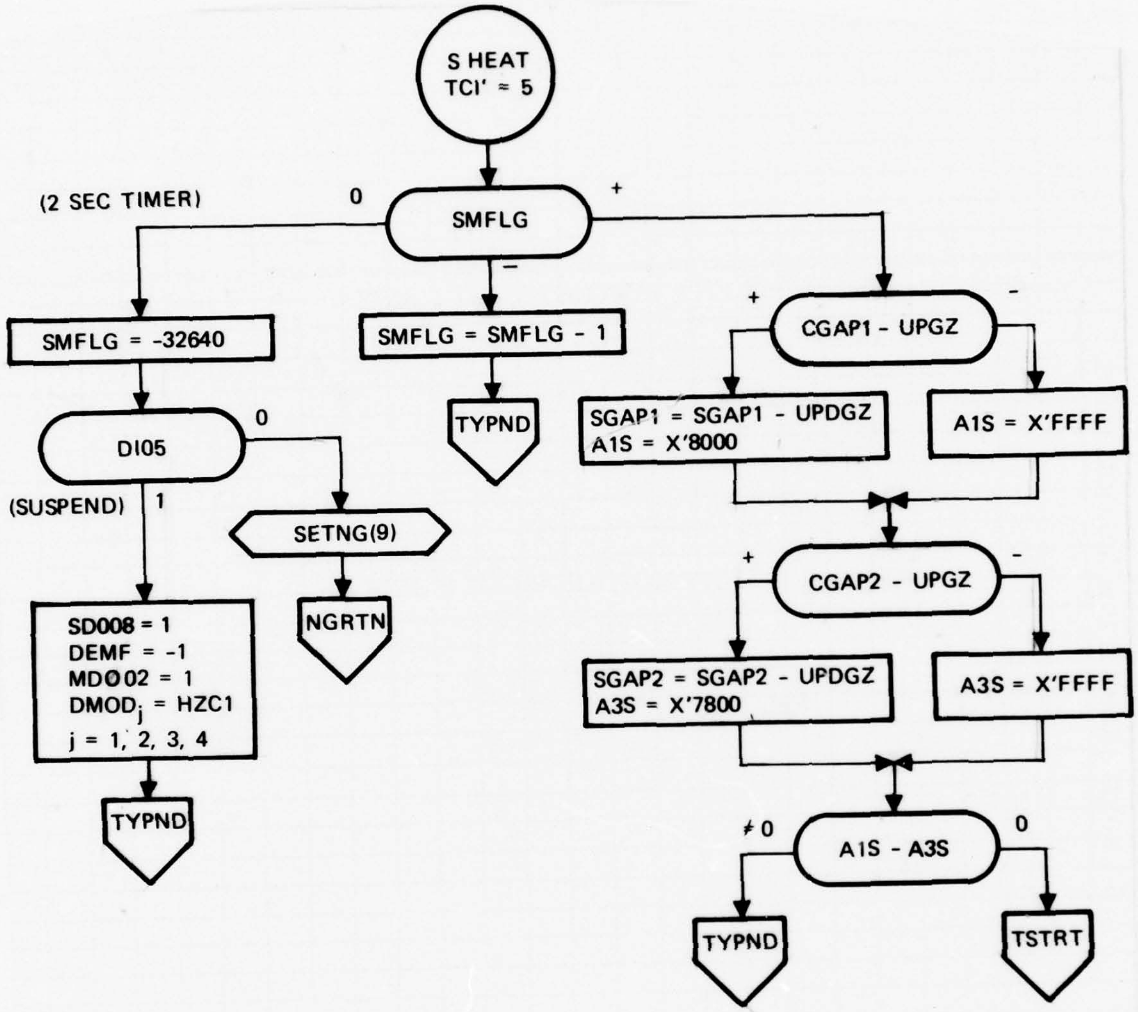


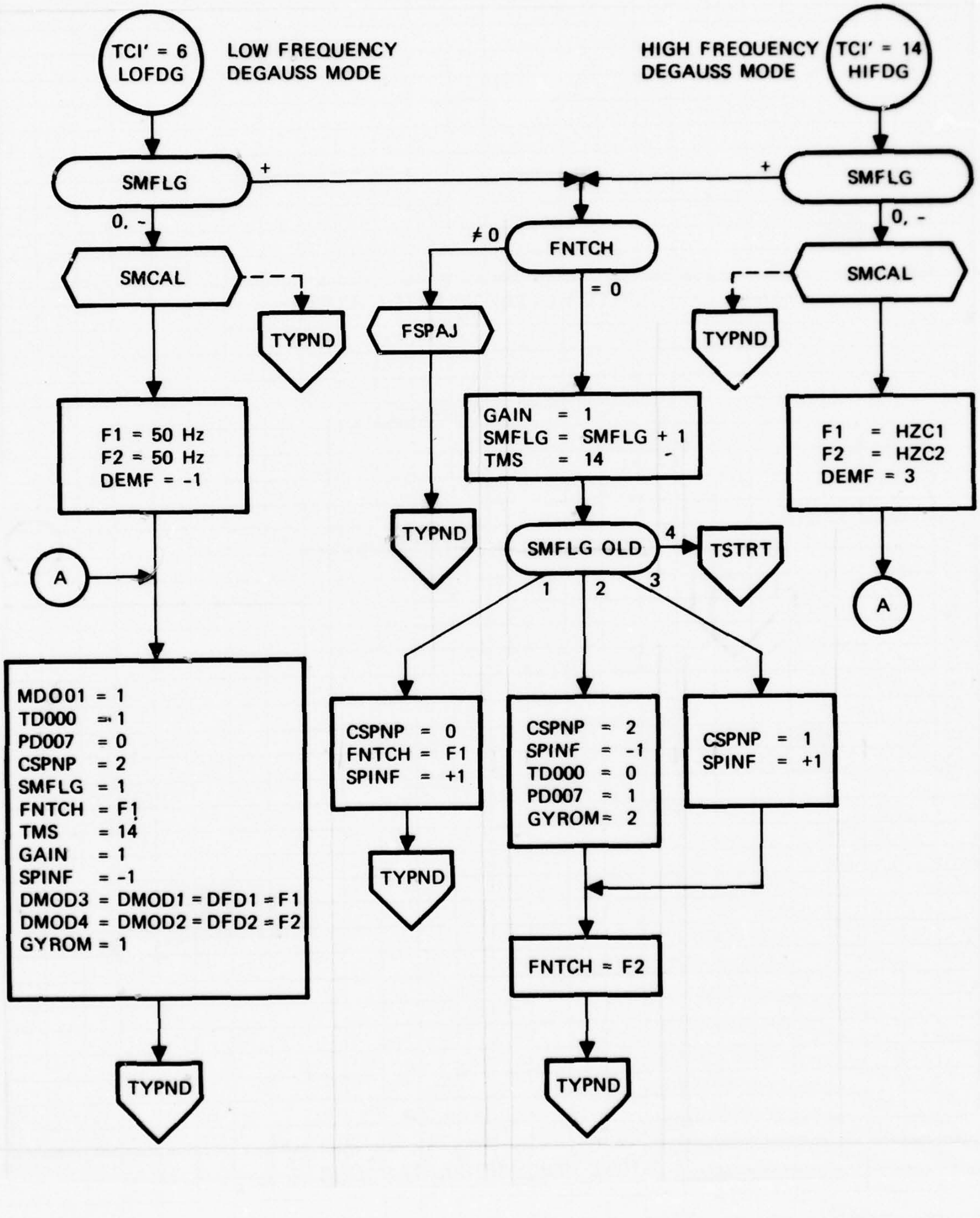
SSPND
TCI' = 3, SUSPEND
SMFLG
(0)
(1)
(2)
(3)
DI05
(1)
(0)
SETNG(8)
NGRTN
SMCA1 + TSPND
(+)
SMCA2 + TSPND
(+)
SDO08 = 1
SMFLG = 1
TYPND
SDO09 = 1
SMFLG = 2
TYPND
IE = X'0000
TIMER = -32 MS
SDO10 = 1*
DELAY 1.25 MS
SD011 = 1*
DELAY 100μS
SD012 = 1*
IE = X'C100
DELAY 5MS
SDO13 = 1*
SMFLG = 3
TYPND
IE = X'F100
DSCRT
DI05
(1)
(0)
TSTRT
SETNG(10)
IE = X'7100
S1S = FFFF
SDO04 = 0
SD008 - 13 = 0
SPEND = 0
NGRTN
*SDO IS ISSUED
VIA WDO AT
TIME BIT IS SET


MONCG
TCI = 16
MANUAL
CHARGE
MONITOR
TCI = 4
CHARGE
MONITOR
CGMON
= 0
SMFLG
≠ 0
A = SMFLG⁻ - 1
CHRG1 = CHRG2 = 0
POINT = ADR FIRST
MDO03 = 1
MDO04 = 0
SMFLG = 2
DEMF = -1
(≠ 0)
A
(= 0)
SMFLG⁺ = A
TYPND
TYPND
POINT
FIFTH
(≠ 0)
TCI - 16
(= 0)
PFLAG = ADR CHRG (1/2)
POINT = ADR FIRST
SMFLG = 2
TSTRT
TYPND

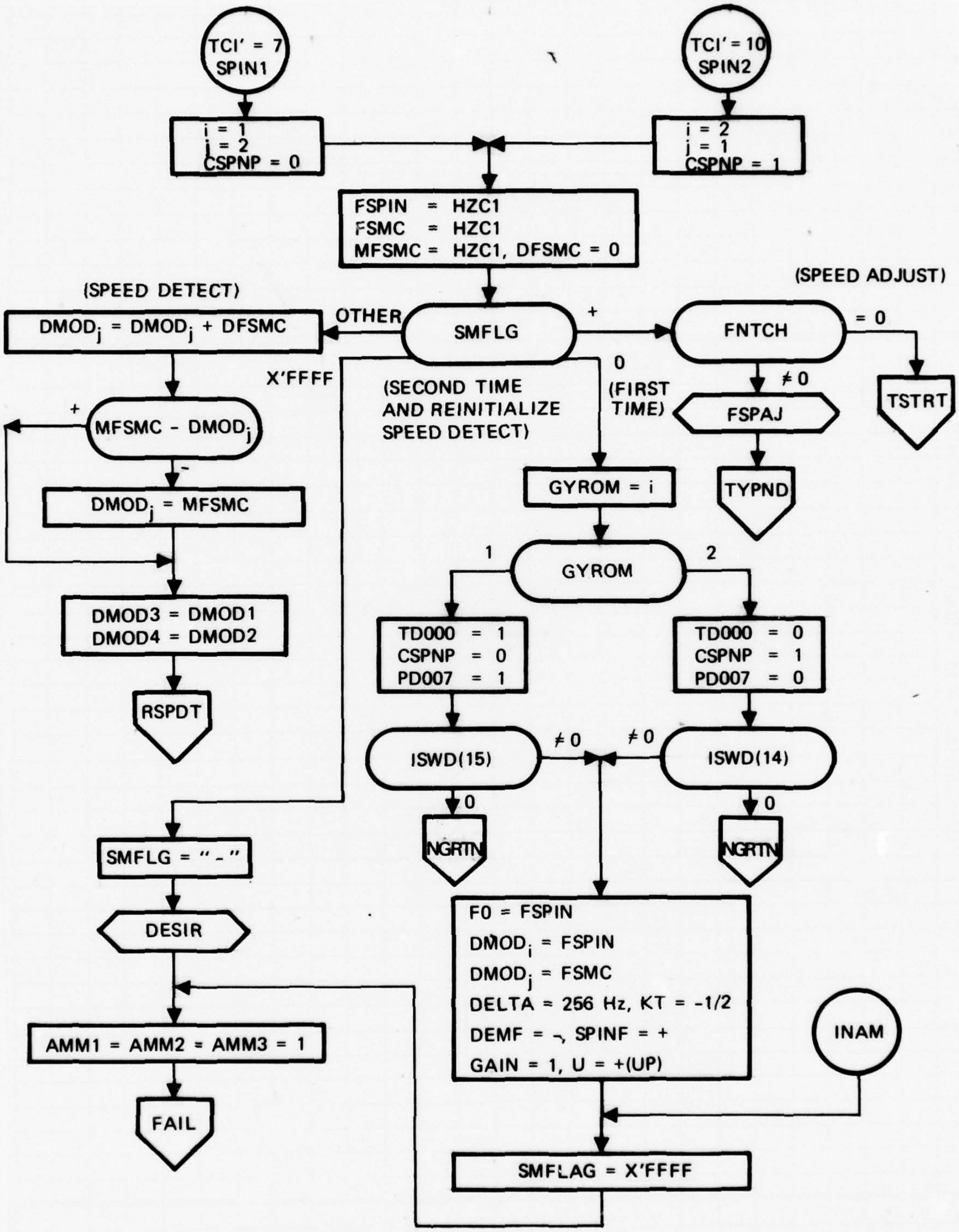

FIRST
THIRD
SDO04 = 1
PDO07 = 1
DMOD2 = DMOD4 = HZC1
DMOD1 = DMOD3 = HZC1 - DFCG
SIS = X'8000
GYROM = 1
PDO07 = 0
DMOD2 = DMOD4 = HZC1 - DFCG
DMOD1 = DMOD3 = HZC1
GYROM = 2
PHICG = CCGB = SCGB = 0
COUNT = SEQ + 13
SMFLG = 3
POINT = POINT + 1
X'CO + DVP1 - DVP2
≠ 0
0
SETNG(11)
X'CO + DVP2 - DVP3
≠ 0
0
SETNG(12)
DVP3 - DV40
≠ 0
0
SETNG(13)
TYPND


SECND
FORTH
SEQ - COUNT
≠ 0
= 0
PHICG = PHICG + DLPCG
CWT = COS (PHICG)
SWT = SIN (PHICG)
CCGB+ = CCGB- + (CWT) (ALUi1)
SCGB+ = SCGB- + (SWT) (ALUi1)
TYPND
CHARGi = √(CCGB)2 + (SCGB)2
CHRG; = CHARGi / (4) CGSL
OVERFLOW?
NO
YES
CHRGi = X'7FFF
CHARGi - CGSL
(+/0)
(-)
SETNGi
i = 37/38
FAIL
LARGE
CHARGE
POINT+ = POINT- + 1
TYPND
IE = X'7100
S15 = X'FFFF
SDO04 = SDO08 - 13 = 0
SPEND+ = SPEND- + 1
SPEND+ - 6
= 0
≠ 0
TCI+ = TCI- - 2
PFLAG = ADR CHRG(1/2)
TSTRC
ABORT
(SHUTDOWN)

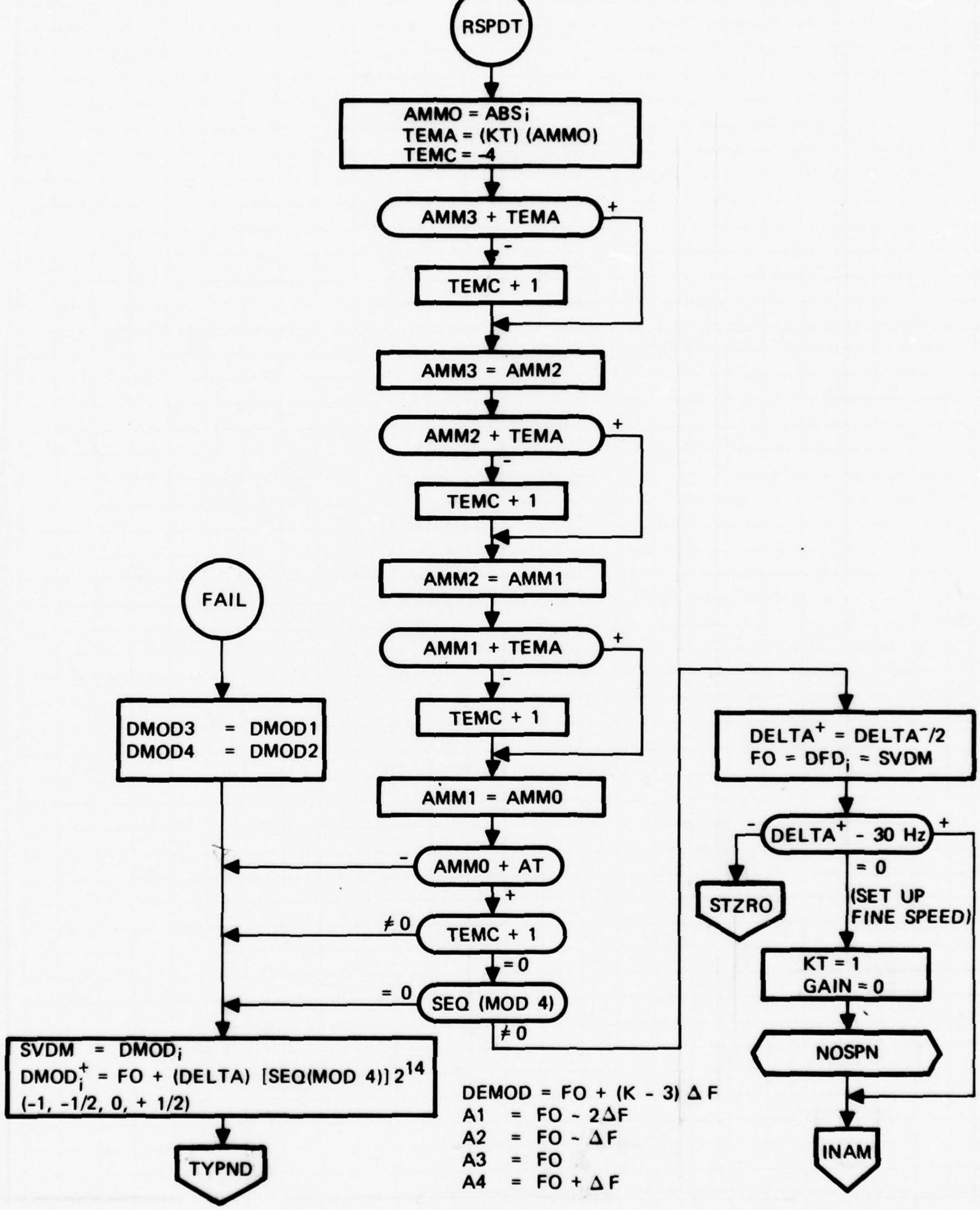

S HEAT
TCI' = 5
SMFLG
(2 SEC TIMER)
0
+
−
SMFLG = -32640
SMFLG = SMFLG - 1
TYPND
CGAP1 - UPGZ
+
-
SGAP1 = SGAP1 - UPDGZ
A1S = X'8000
A1S = X'FFFF
DI05
0
(SUSPEND)
1
SETNG(9)
NGRTN
CGAP2 - UPGZ
+
-
SD008 = 1
DEMF = -1
MDØ02 = 1
DMOD$_j$ = HZC1
j = 1, 2, 3, 4
SGAP2 = SGAP2 - UPDGZ
A3S = X'7800
A3S = X'FFFF
TYPND
A1S - A3S
≠ 0
0
TYPND
TSTRT

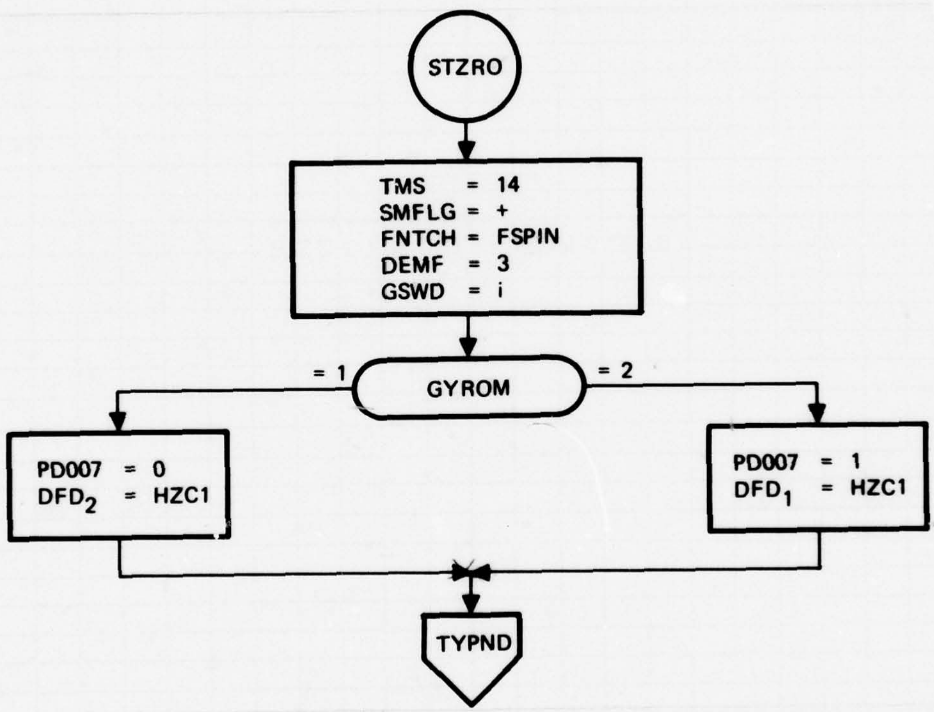


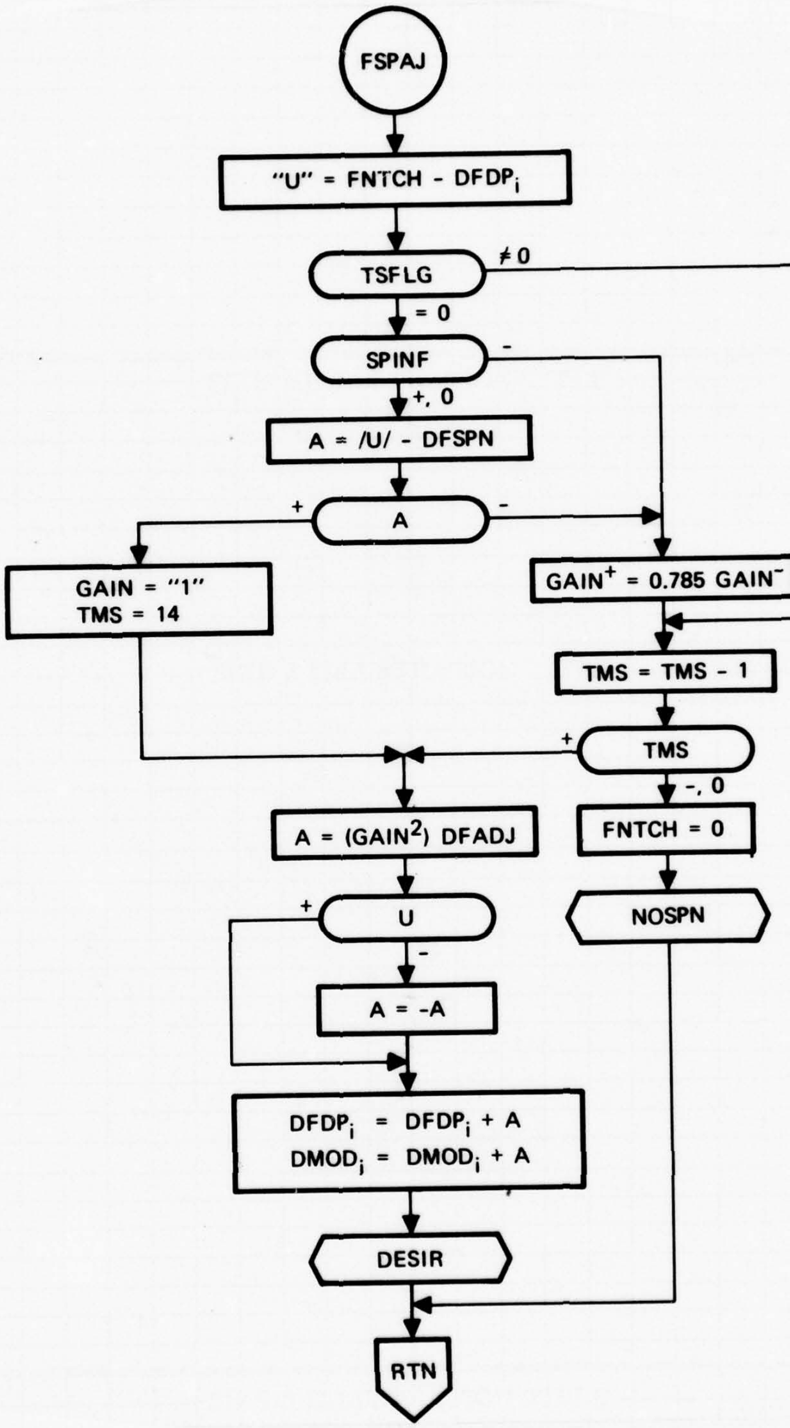
TCI' = 6
LOFDG
LOW FREQUENCY
DEGAUSS MODE
HIGH FREQUENCY
DEGAUSS MODE
TCI' = 14
HIFDG
SMFLG
+
0, -
SMCAL
TYPND
FNTCH
≠ 0
= 0
FSPAJ
GAIN = 1
SMFLG = SMFLG + 1
TMS = 14
F1 = 50 Hz
F2 = 50 Hz
DEMF = -1
F1 = HZC1
F2 = HZC2
DEMF = 3
A
SMFLG OLD
4
TSTRT
1
2
3
MDO01 = 1
TD000 = 1
PD007 = 0
CSPNP = 2
SMFLG = 1
FNTCH = F1
TMS = 14
GAIN = 1
SPINF = -1
DMOD3 = DMOD1 = DFD1 = F1
DMOD4 = DMOD2 = DFD2 = F2
GYROM = 1
CSPNP = 0
FNTCH = F1
SPINF = +1
CSPNP = 2
SPINF = -1
TD000 = 0
PD007 = 1
GYROM = 2
CSPNP = 1
SPINF = +1
FNTCH = F2

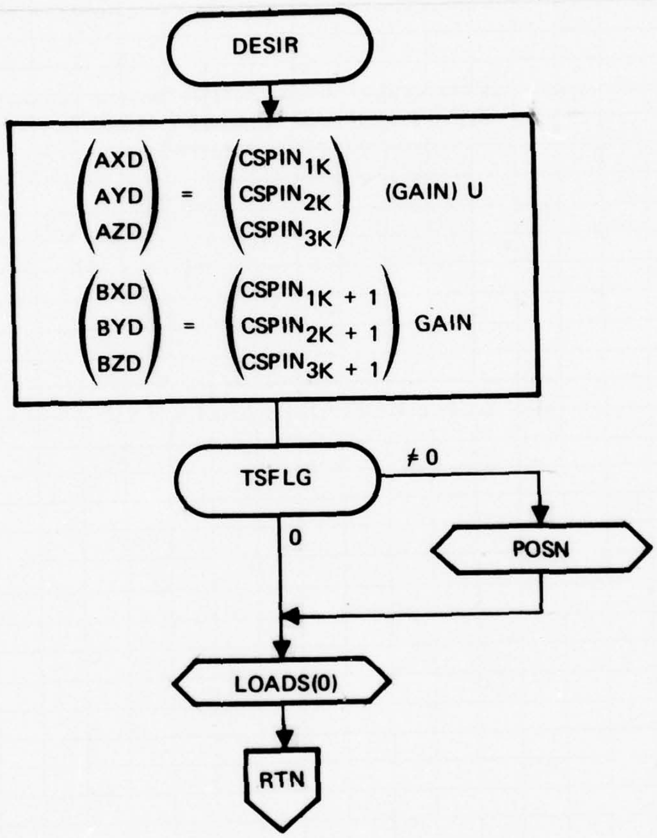


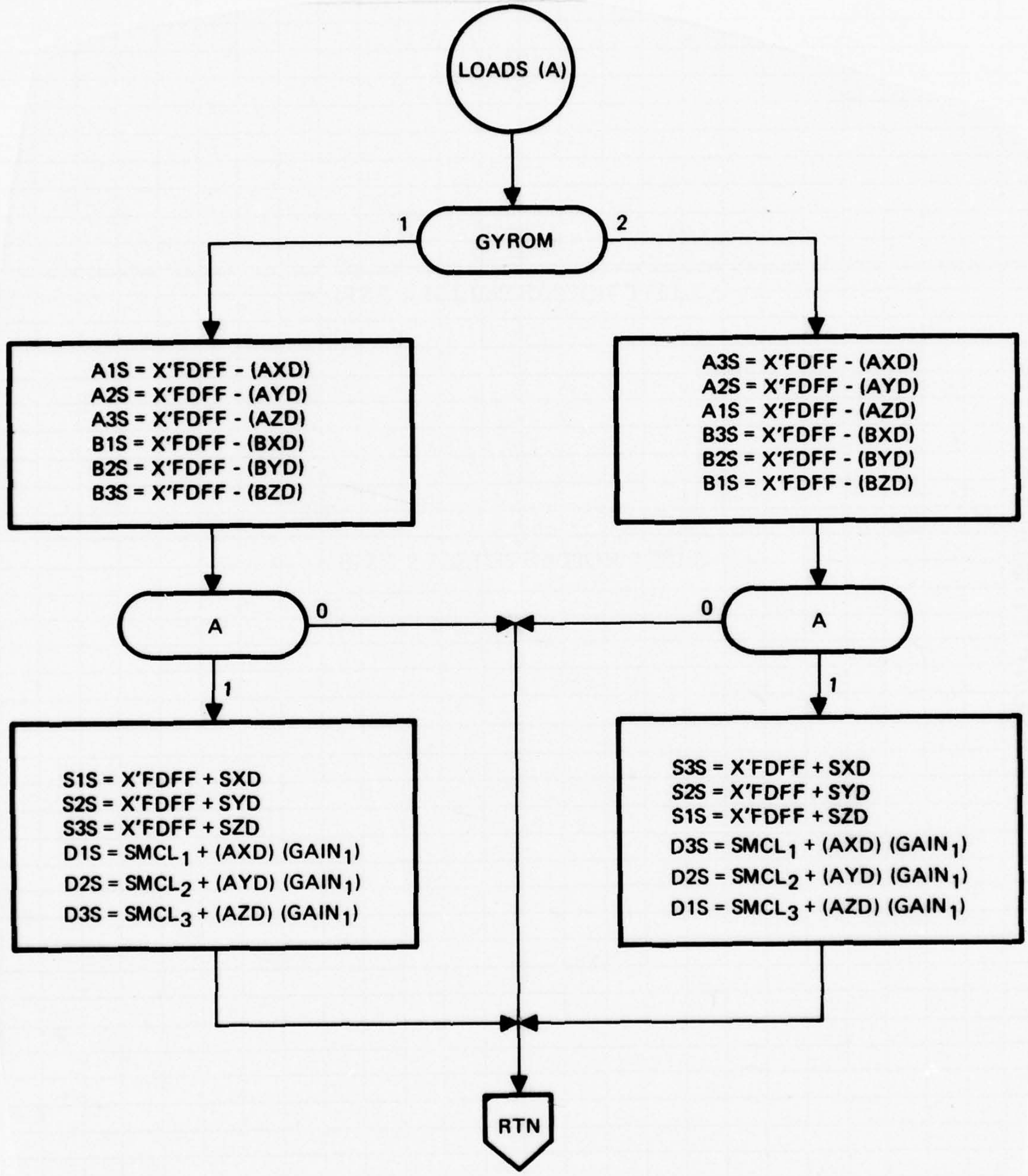
TCI' = 7
SPIN1
TCI' = 10
SPIN2
i = 1
j = 2
CSPNP = 0
i = 2
j = 1
CSPNP = 1
FSPIN = HZC1
FSMC = HZC1
MFSMC = HZC1, DFSMC = 0
(SPEED DETECT)
(SPEED ADJUST)
DMODj = DMODj + DFSMC
OTHER
SMFLG
+
FNTCH
= 0
X'FFFF
0
(SECOND TIME AND REINITIALIZE SPEED DETECT)
(FIRST TIME)
≠ 0
FSPAJ
TSTRT
MFSMC - DMODj
DMODj = MFSMC
GYROM = i
TYPND
GYROM
DMOD3 = DMOD1
DMOD4 = DMOD2
TD000 = 1
CSPNP = 0
PD007 = 1
TD000 = 0
CSPNP = 1
PD007 = 0
RSPDT
ISWD(15)
ISWD(14)
NGRTN
NGRTN
SMFLG = "-"
DESIR
F0 = FSPIN
DMODi = FSPIN
DMODj = FSMC
DELTA = 256 Hz, KT = -1/2
DEMF = ¬, SPINF = +
GAIN = 1, U = +(UP)
INAM
AMM1 = AMM2 = AMM3 = 1
FAIL
SMFLAG = X'FFFF

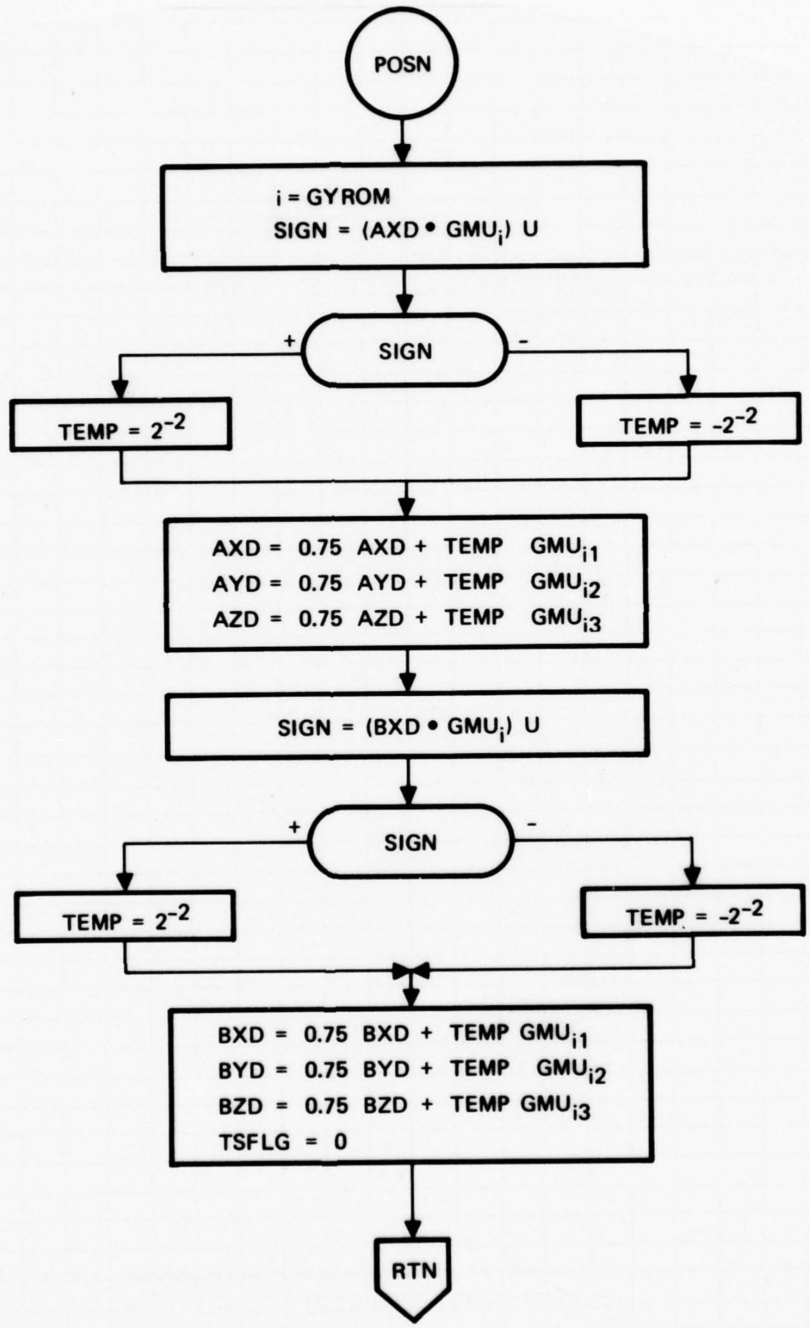

RSPDT
AMMO = ABSi
TEMA = (KT) (AMMO)
TEMC = -4
AMM3 + TEMA
+
-
TEMC + 1
AMM3 = AMM2
AMM2 + TEMA
+
-
TEMC + 1
AMM2 = AMM1
FAIL
AMM1 + TEMA
+
-
TEMC + 1
DMOD3 = DMOD1
DMOD4 = DMOD2
AMM1 = AMM0
DELTA+ = DELTA-/2
FO = DFDi = SVDM
-
DELTA+ - 30 Hz
+
-
AMM0 + AT
+
= 0
STZRO
(SET UP
FINE SPEED)
≠ 0
TEMC + 1
= 0
KT = 1
GAIN = 0
= 0
SEQ (MOD 4)
≠ 0
NOSPN
SVDM = DMODi
DMODi+ = FO + (DELTA) [SEQ(MOD 4)] 2^14
(-1, -1/2, 0, + 1/2)
DEMOD = FO + (K - 3) ΔF
A1 = FO - 2ΔF
A2 = FO - ΔF
A3 = FO
A4 = FO + ΔF
TYPND
INAM

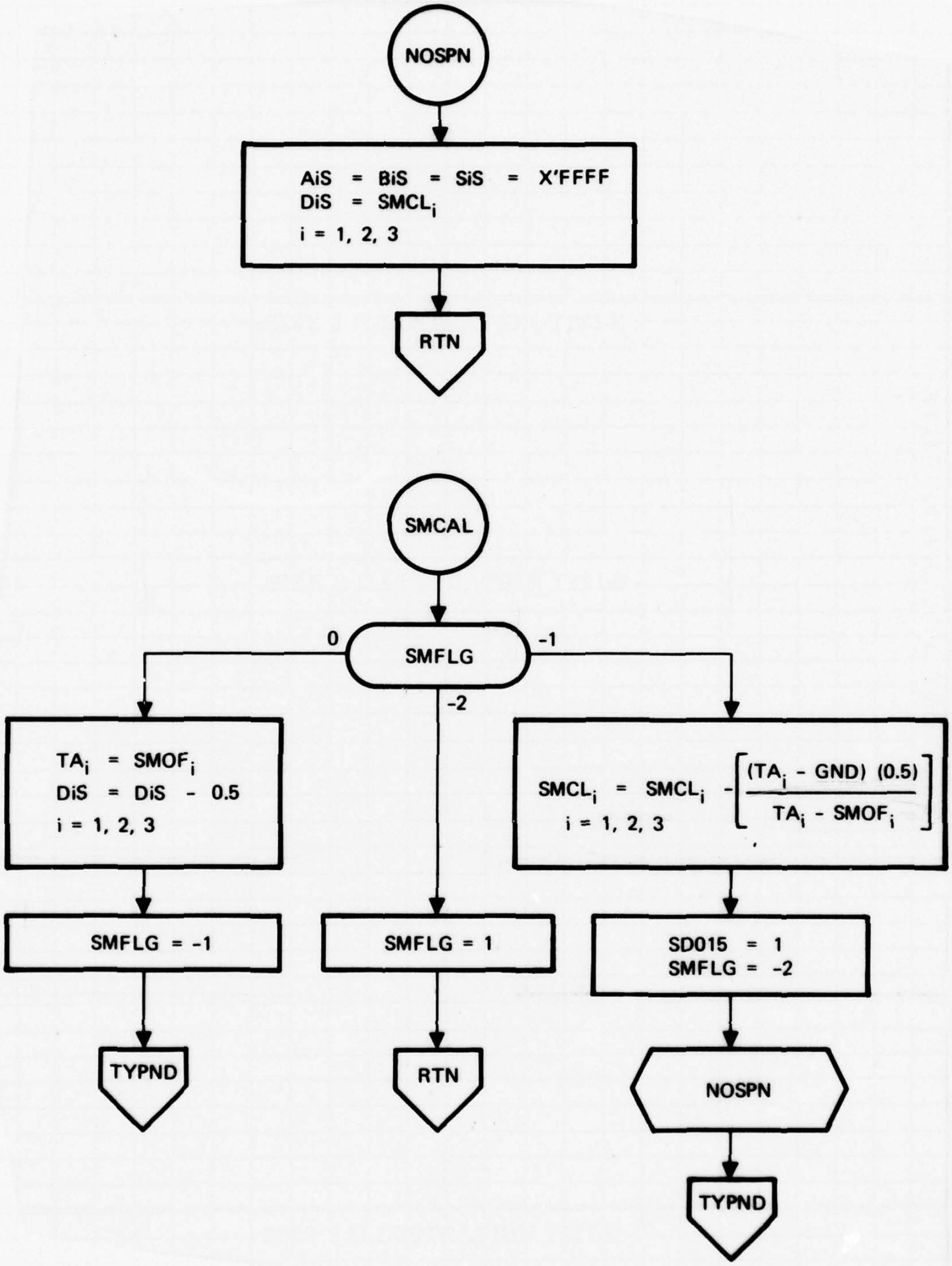

STZRO
TMS = 14
SMFLG = +
FNTCH = FSPIN
DEMF = 3
GSWD = i
GYROM
= 1
= 2
PD007 = 0
DFD$_2$ = HZC1
PD007 = 1
DFD$_1$ = HZC1
TYPND

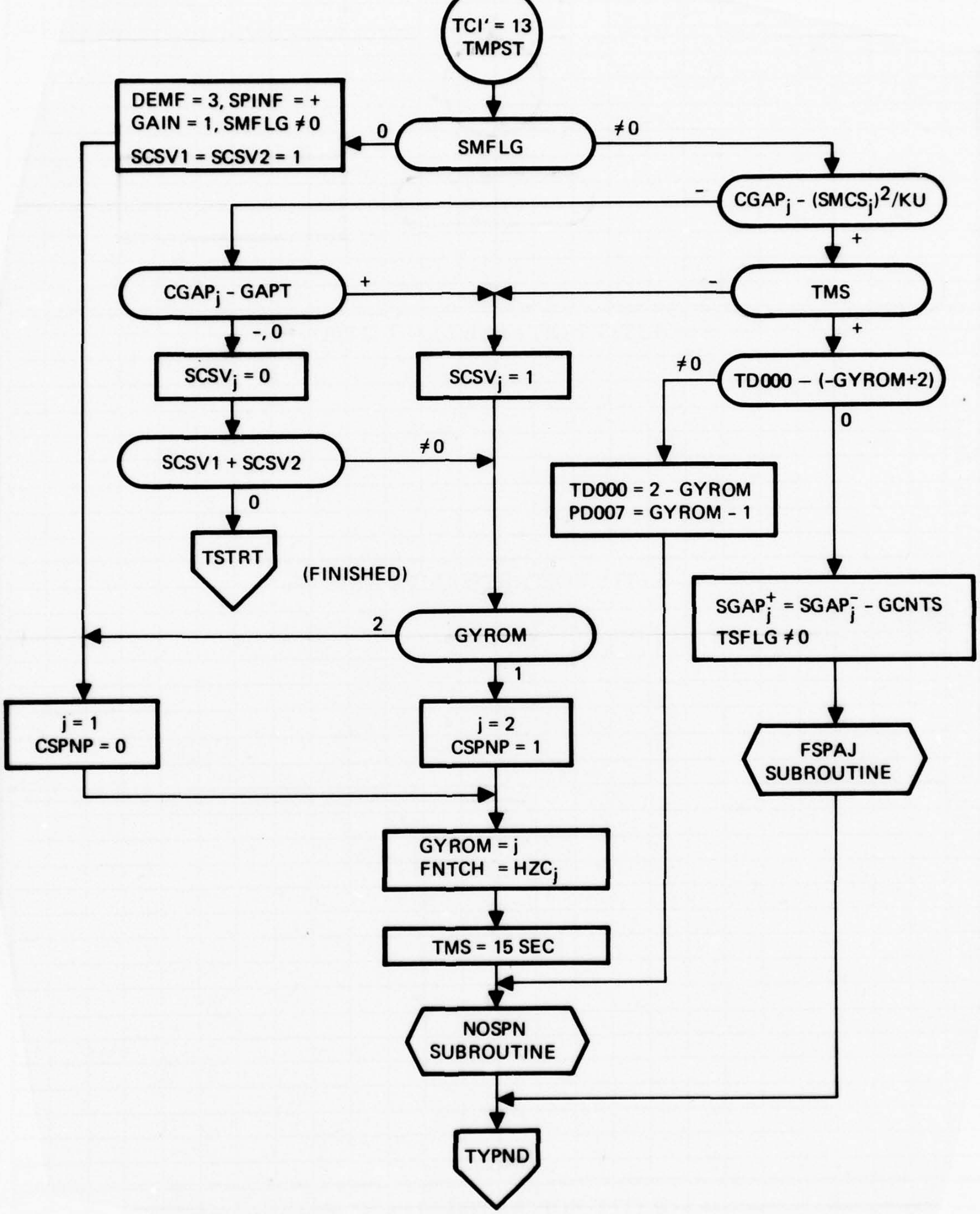

FSPAJ
"U" = FNTCH - DFDP$_i$
TSFLG
≠ 0
= 0
SPINF
-
+, 0
A = /U/ - DFSPN
A
+
-
GAIN = "1"
TMS = 14
GAIN$^+$ = 0.785 GAIN$^-$
TMS = TMS - 1
TMS
+
-, 0
A = (GAIN^2) DFADJ
FNTCH = 0
U
+
-
NOSPN
A = -A
DFDP$_i$ = DFDP$_i$ + A
DMOD$_i$ = DMOD$_i$ + A
DESIR
RTN

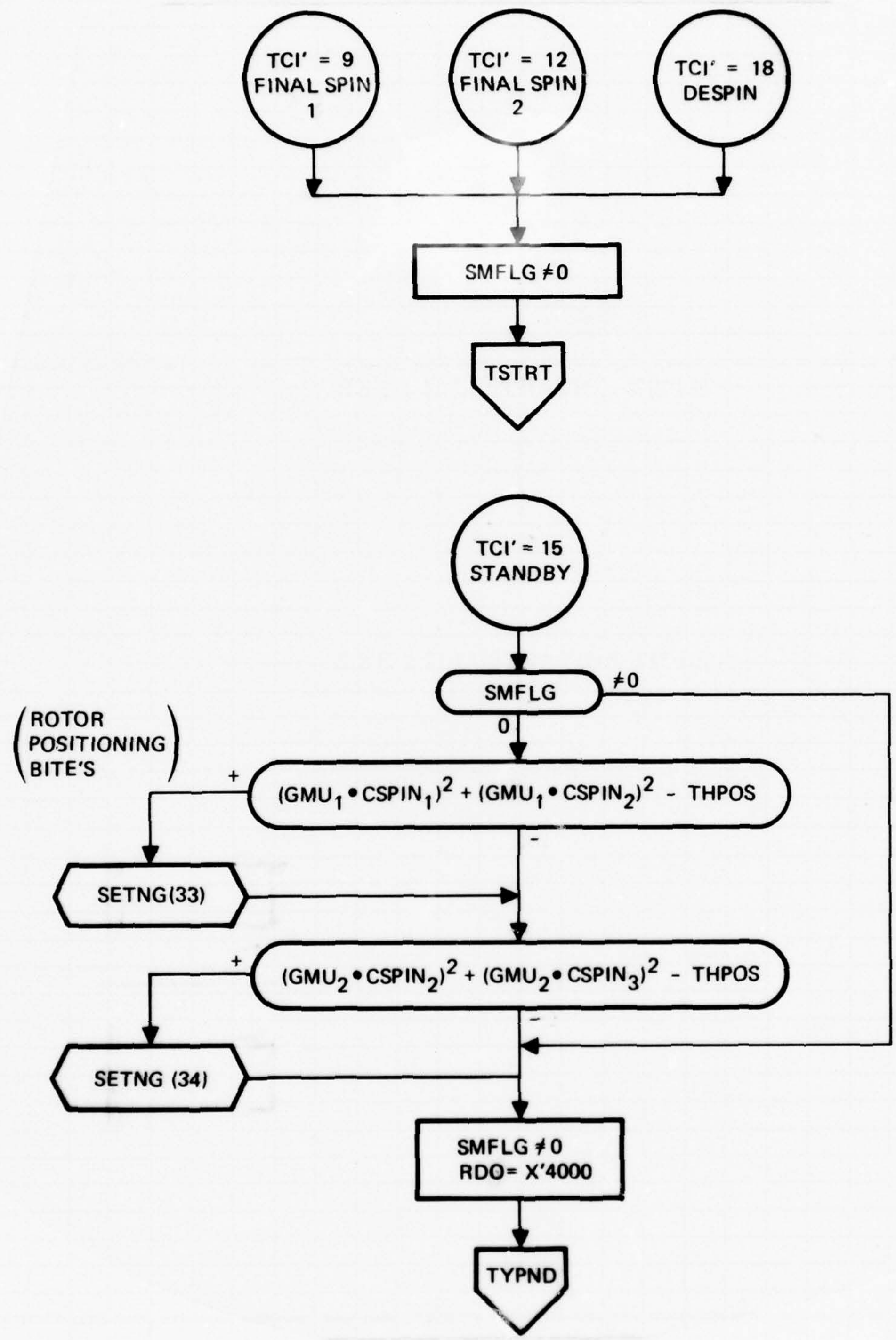

DESIR
AXD
AYD
AZD
=
CSPIN1K
CSPIN2K
CSPIN3K
(GAIN) U
BXD
BYD
BZD
=
CSPIN1K + 1
CSPIN2K + 1
CSPIN3K + 1
GAIN
TSFLG
≠ 0
0
POSN
LOADS(0)
RTN

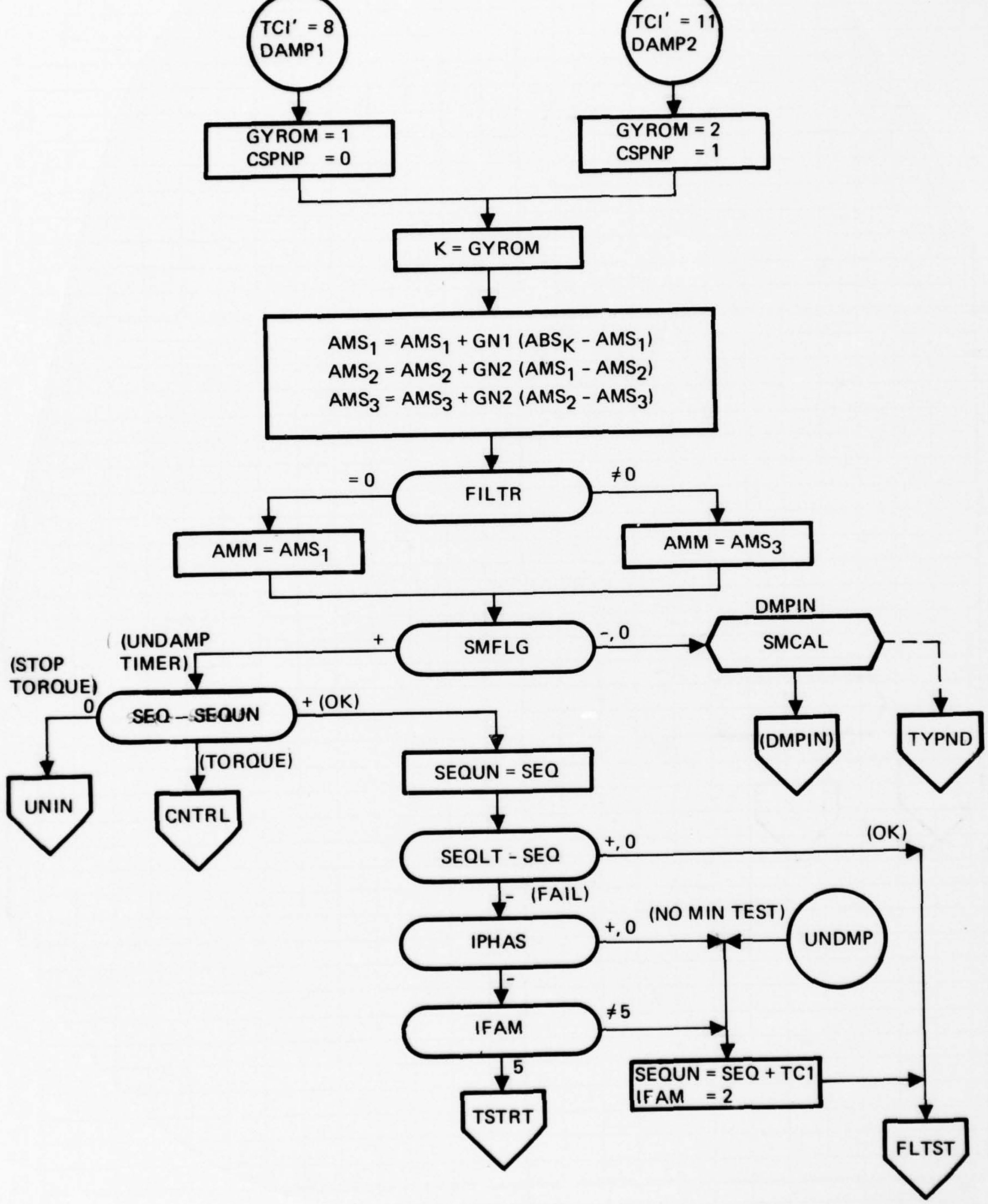

LOADS (A)
GYROM
1
2
A1S = X'FDFF - (AXD)
A2S = X'FDFF - (AYD)
A3S = X'FDFF - (AZD)
B1S = X'FDFF - (BXD)
B2S = X'FDFF - (BYD)
B3S = X'FDFF - (BZD)
A3S = X'FDFF - (AXD)
A2S = X'FDFF - (AYD)
A1S = X'FDFF - (AZD)
B3S = X'FDFF - (BXD)
B2S = X'FDFF - (BYD)
B1S = X'FDFF - (BZD)
A
0
1
A
0
1
S1S = X'FDFF + SXD
S2S = X'FDFF + SYD
S3S = X'FDFF + SZD
D1S = SMCL1 + (AXD) (GAIN1)
D2S = SMCL2 + (AYD) (GAIN1)
D3S = SMCL3 + (AZD) (GAIN1)
S3S = X'FDFF + SXD
S2S = X'FDFF + SYD
S1S = X'FDFF + SZD
D3S = SMCL1 + (AXD) (GAIN1)
D2S = SMCL2 + (AYD) (GAIN1)
D1S = SMCL3 + (AZD) (GAIN1)
RTN

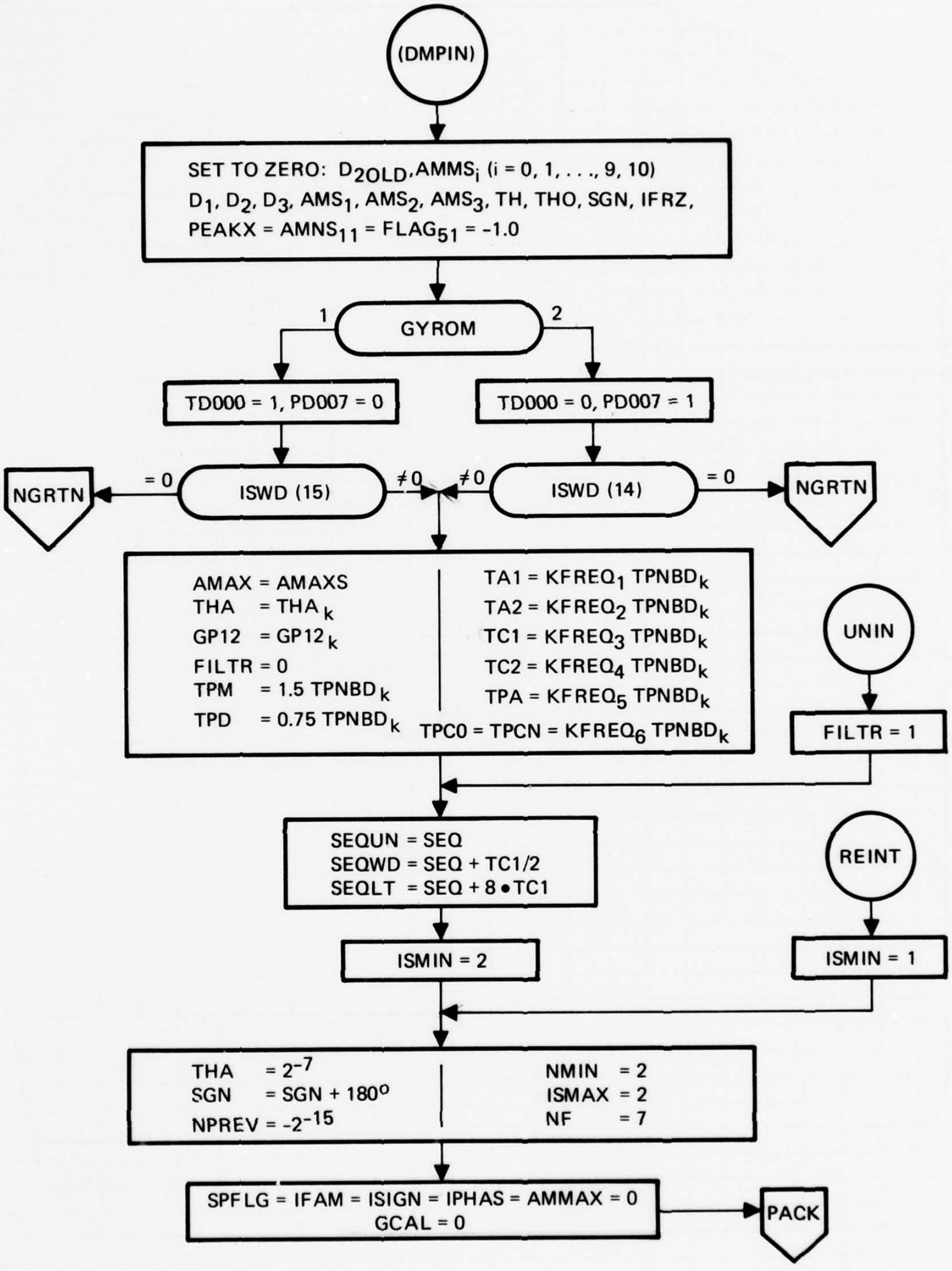

POSN
i = GYROM
SIGN = (AXD • GMU$_i$) U
SIGN
+
-
TEMP = 2^{-2}
TEMP = -2^{-2}
AXD = 0.75 AXD + TEMP GMU$_{i1}$
AYD = 0.75 AYD + TEMP GMU$_{i2}$
AZD = 0.75 AZD + TEMP GMU$_{i3}$
SIGN = (BXD • GMU$_i$) U
SIGN
+
-
TEMP = 2^{-2}
TEMP = -2^{-2}
BXD = 0.75 BXD + TEMP GMU$_{i1}$
BYD = 0.75 BYD + TEMP GMU$_{i2}$
BZD = 0.75 BZD + TEMP GMU$_{i3}$
TSFLG = 0
RTN

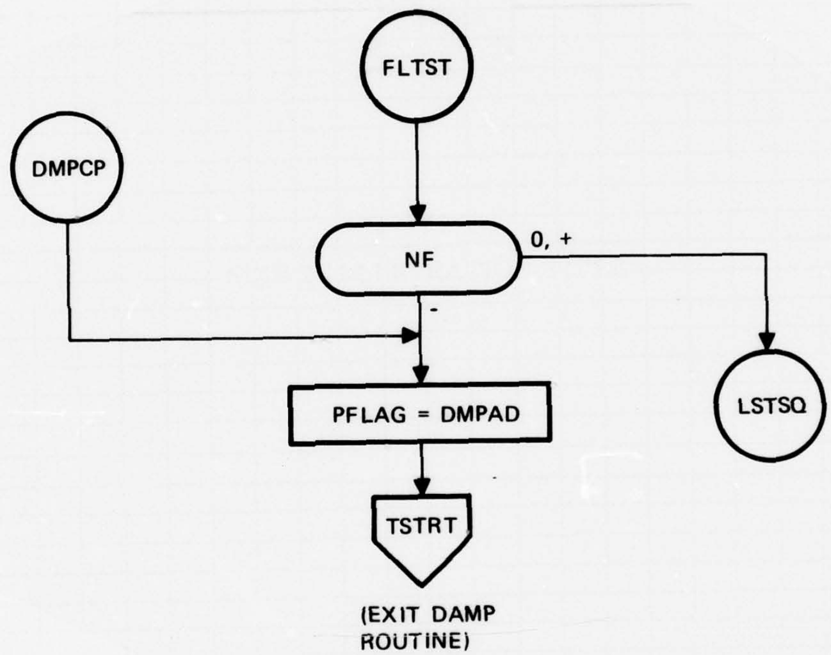

NOSPN
AiS = BiS = SiS = X'FFFF
DiS = SMCLi
i = 1, 2, 3
RTN
SMCAL
SMFLG
0
-1
-2
TAi = SMOFi
DiS = DiS - 0.5
i = 1, 2, 3
SMCLi = SMCLi - [(TAi - GND) (0.5) / TAi - SMOFi]
i = 1, 2, 3
SMFLG = -1
SMFLG = 1
SD015 = 1
SMFLG = -2
TYPND
RTN
NOSPN
TYPND

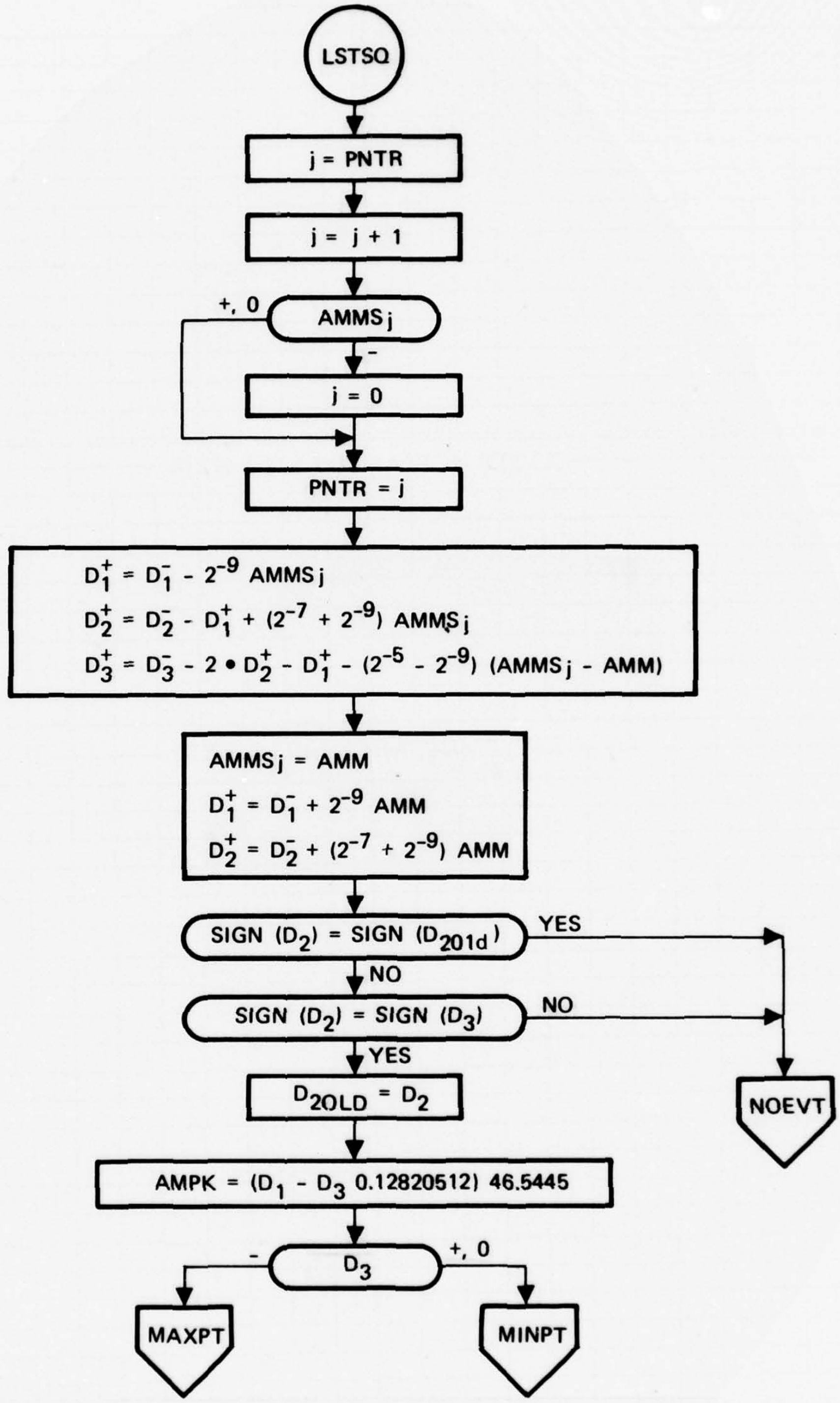

TCI' = 13
TMPST
DEMF = 3, SPINF = +
GAIN = 1, SMFLG ≠ 0
SCSV1 = SCSV2 = 1
0
SMFLG
≠0
-
$CGAP_j - (SMCS_j)^2/KU$
+
$CGAP_j$ - GAPT
+
-
TMS
-, 0
+
$SCSV_j = 0$
$SCSV_j = 1$
≠0
TD000 – (-GYROM+2)
0
SCSV1 + SCSV2
≠0
TD000 = 2 - GYROM
PD007 = GYROM - 1
0
TSTRT
(FINISHED)
$SGAP_j^+ = SGAP_j^- - GCNTS$
TSFLG ≠ 0
2
GYROM
1
j = 1
CSPNP = 0
j = 2
CSPNP = 1
FSPAJ
SUBROUTINE
GYROM = j
$FNTCH = HZC_j$
TMS = 15 SEC
NOSPN
SUBROUTINE
TYPND

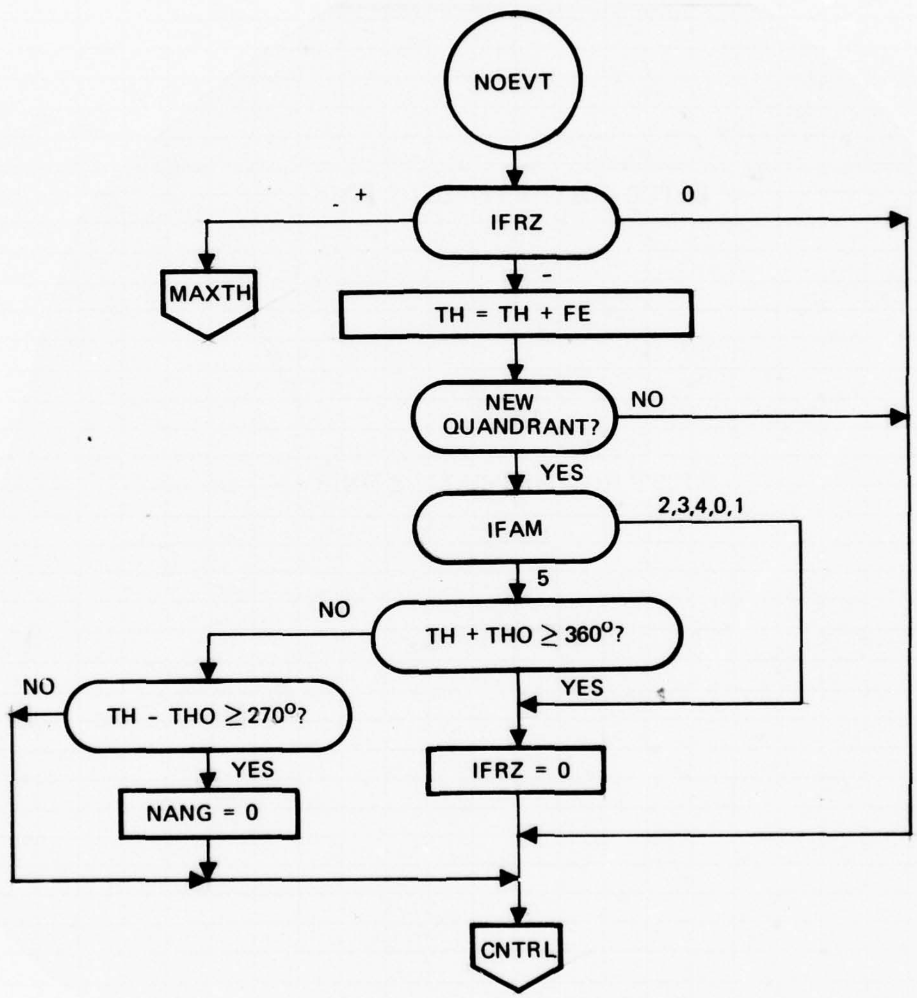

TCI' = 9
FINAL SPIN
1
TCI' = 12
FINAL SPIN
2
TCI' = 18
DESPIN
SMFLG ≠ 0
TSTRT
TCI' = 15
STANDBY
SMFLG
≠0
0
ROTOR
POSITIONING
BITE'S
+
(GMU1 • CSPIN1)2 + (GMU1 • CSPIN2)2 - THPOS
-
SETNG(33)
+
(GMU2 • CSPIN2)2 + (GMU2 • CSPIN3)2 - THPOS
-
SETNG (34)
SMFLG ≠ 0
RDO= X'4000
TYPND

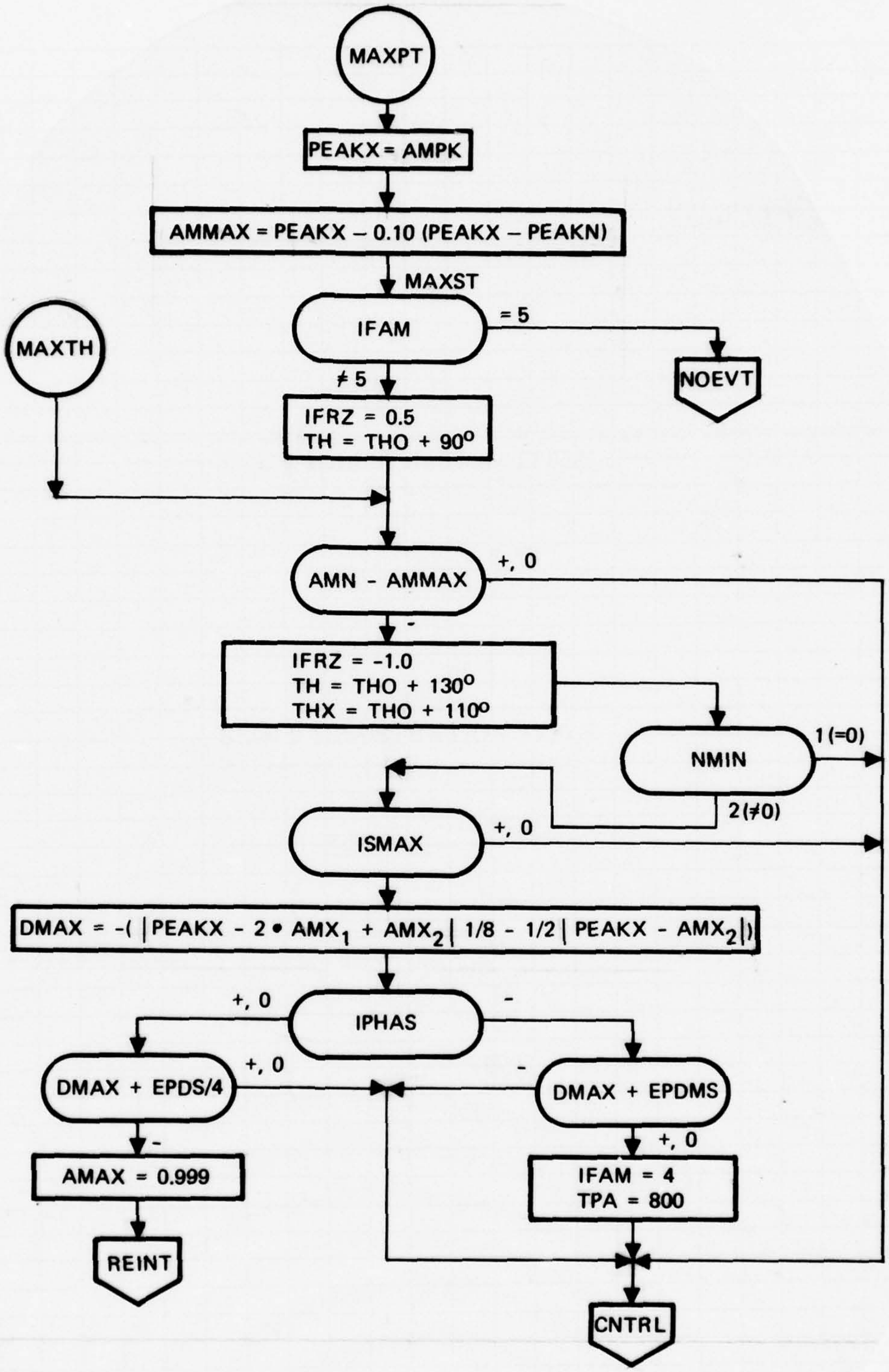

TCI' = 8
DAMP1
TCI' = 11
DAMP2
GYROM = 1
CSPNP = 0
GYROM = 2
CSPNP = 1
K = GYROM
$AMS_1 = AMS_1 + GN1\ (ABS_K - AMS_1)$
$AMS_2 = AMS_2 + GN2\ (AMS_1 - AMS_2)$
$AMS_3 = AMS_3 + GN2\ (AMS_2 - AMS_3)$
= 0
FILTR
≠ 0
$AMM = AMS_1$
$AMM = AMS_3$
DMPIN
(UNDAMP
TIMER)
+
SMFLG
–, 0
SMCAL
(STOP
TORQUE)
0
SEQ – SEQUN
+ (OK)
(DMPIN)
TYPND
(TORQUE)
SEQUN = SEQ
UNIN
CNTRL
SEQLT - SEQ
+, 0
(OK)
– (FAIL)
(NO MIN TEST)
IPHAS
+, 0
UNDMP
–
IFAM
≠ 5
5
SEQUN = SEQ + TC1
IFAM = 2
TSTRT
FLTST

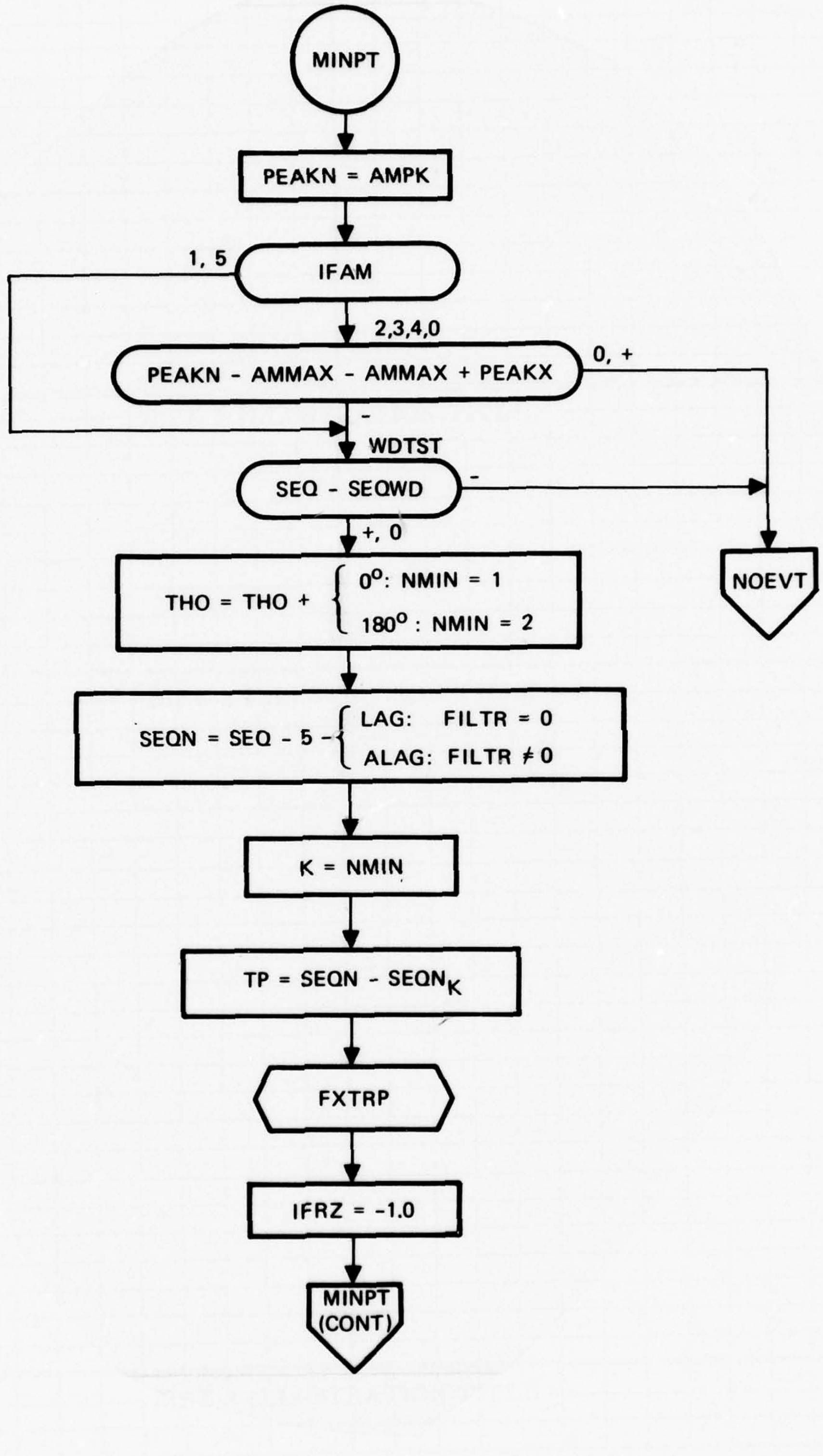

(DMPIN)
SET TO ZERO: D2OLD, AMMSi (i = 0, 1, . . ., 9, 10)
D1, D2, D3, AMS1, AMS2, AMS3, TH, THO, SGN, IFRZ,
PEAKX = AMNS11 = FLAG51 = -1.0
GYROM
1
2
TD000 = 1, PD007 = 0
TD000 = 0, PD007 = 1
ISWD (15)
ISWD (14)
= 0
≠ 0
≠ 0
= 0
NGRTN
NGRTN
AMAX = AMAXS
THA = THAk
GP12 = GP12k
FILTR = 0
TPM = 1.5 TPNBDk
TPD = 0.75 TPNBDk
TA1 = KFREQ1 TPNBDk
TA2 = KFREQ2 TPNBDk
TC1 = KFREQ3 TPNBDk
TC2 = KFREQ4 TPNBDk
TPA = KFREQ5 TPNBDk
TPC0 = TPCN = KFREQ6 TPNBDk
UNIN
FILTR = 1
SEQUN = SEQ
SEQWD = SEQ + TC1/2
SEQLT = SEQ + 8 • TC1
REINT
ISMIN = 2
ISMIN = 1
THA = 2-7
SGN = SGN + 180°
NPREV = -2-15
NMIN = 2
ISMAX = 2
NF = 7
SPFLG = IFAM = ISIGN = IPHAS = AMMAX = 0
GCAL = 0
PACK

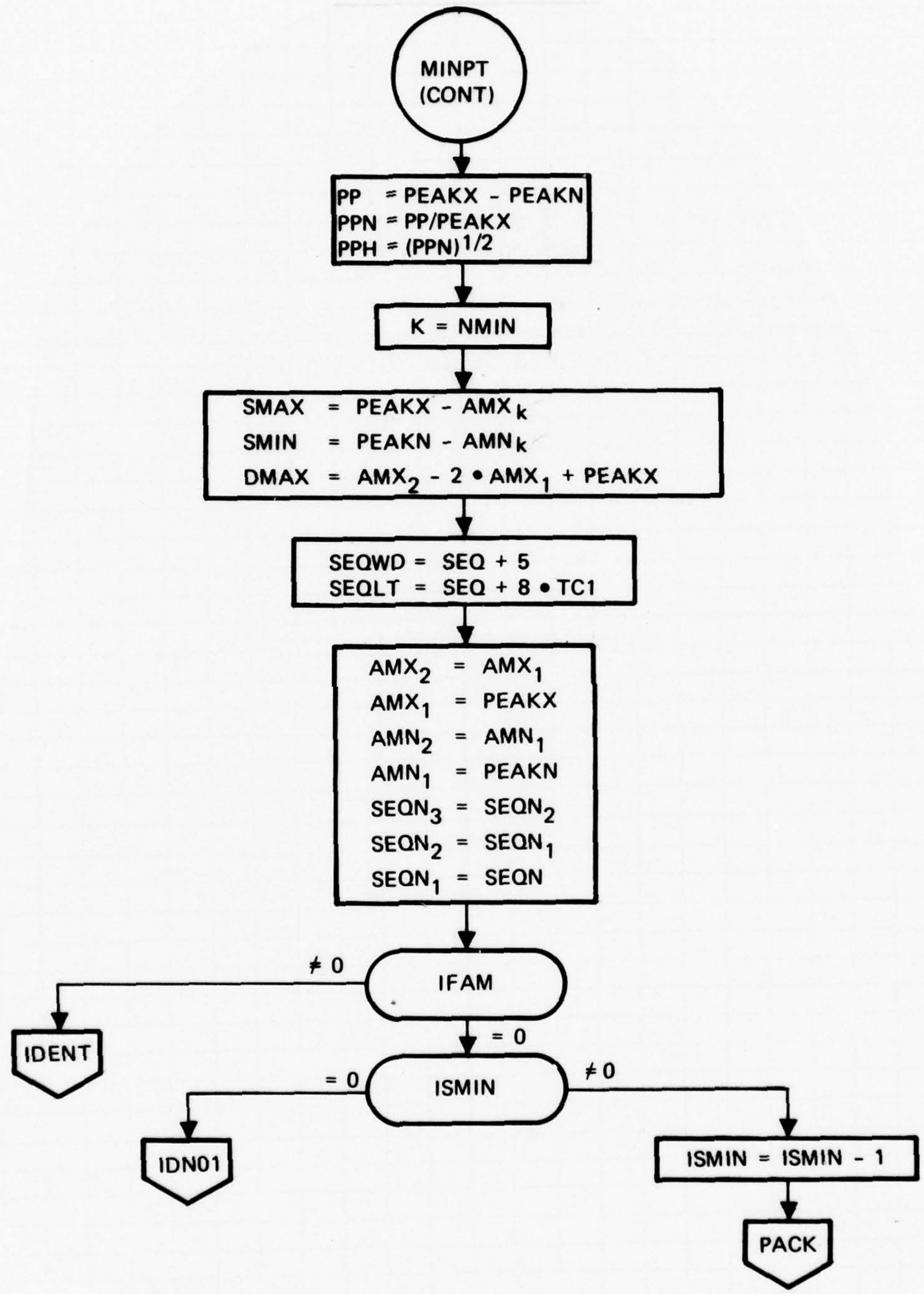

FLTST
DMPCP
NF
0, +
-
LSTSQ
PFLAG = DMPAD
TSTRT
(EXIT DAMP ROUTINE)

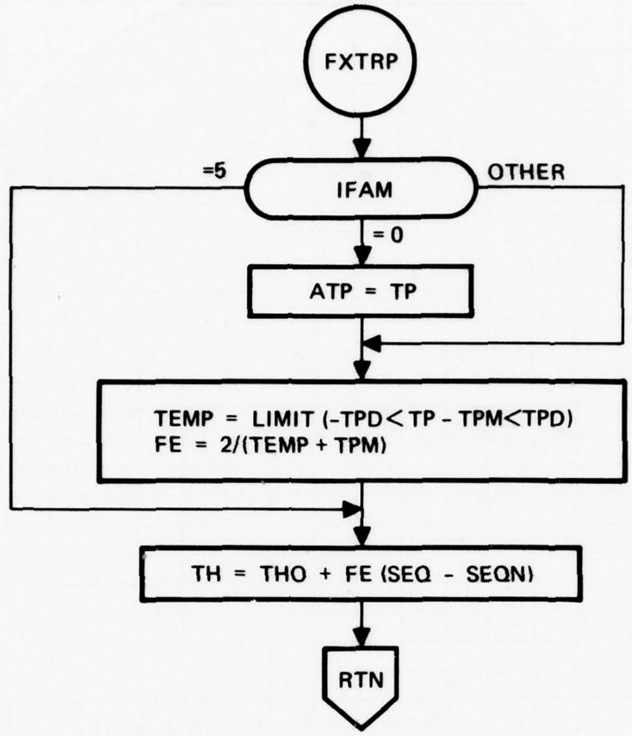

LSTSQ
j = PNTR
j = j + 1
+, 0
AMMS j
-
j = 0
PNTR = j
$D_1^+ = D_1^- - 2^{-9}\ AMMS_j$
$D_2^+ = D_2^- - D_1^+ + (2^{-7} + 2^{-9})\ AMMS_j$
$D_3^+ = D_3^- - 2 \bullet D_2^+ - D_1^+ - (2^{-5} - 2^{-9})\ (AMMS_j - AMM)$
$AMMS_j = AMM$
$D_1^+ = D_1^- + 2^{-9}\ AMM$
$D_2^+ = D_2^- + (2^{-7} + 2^{-9})\ AMM$
$SIGN\ (D_2) = SIGN\ (D_{2OLD})$
YES
NO
$SIGN\ (D_2) = SIGN\ (D_3)$
NO
YES
$D_{2OLD} = D_2$
NOEVT
$AMPK = (D_1 - D_3\ 0.12820512)\ 46.5445$
-
D_3
+, 0
MAXPT
MINPT

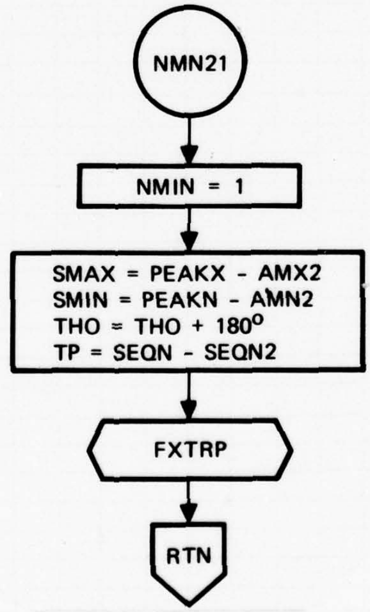

NOEVT
IFRZ
+
0
-
MAXTH
TH = TH + FE
NEW QUANDRANT?
NO
YES
IFAM
2,3,4,0,1
5
TH + THO ≥ 360°?
NO
YES
TH - THO ≥ 270°?
NO
YES
NANG = 0
IFRZ = 0
CNTRL

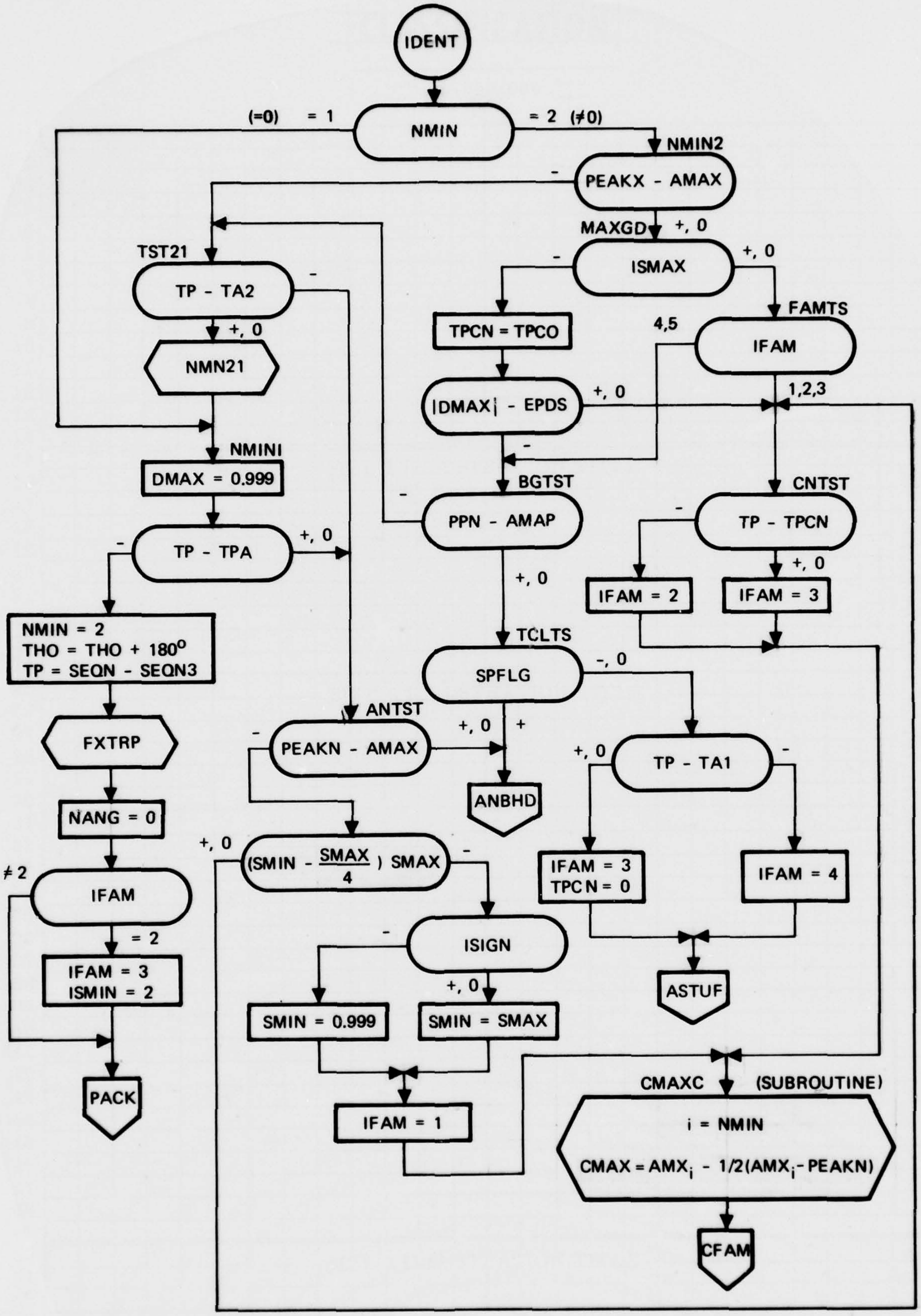

MAXPT
PEAKX = AMPK
AMMAX = PEAKX – 0.10 (PEAKX – PEAKN)
MAXST
IFAM
= 5
NOEVT
MAXTH
≠ 5
IFRZ = 0.5
TH = THO + 90°
AMN - AMMAX
+, 0
-
IFRZ = -1.0
TH = THO + 130°
THX = THO + 110°
NMIN
1 (=0)
2(≠0)
ISMAX
+, 0
DMAX = -(|PEAKX - 2 • AMX1 + AMX2| 1/8 - 1/2 | PEAKX - AMX2|)
IPHAS
+, 0
-
DMAX + EPDS/4
+, 0
-
DMAX + EPDMS
-
+, 0
AMAX = 0.999
IFAM = 4
TPA = 800
REINT
CNTRL

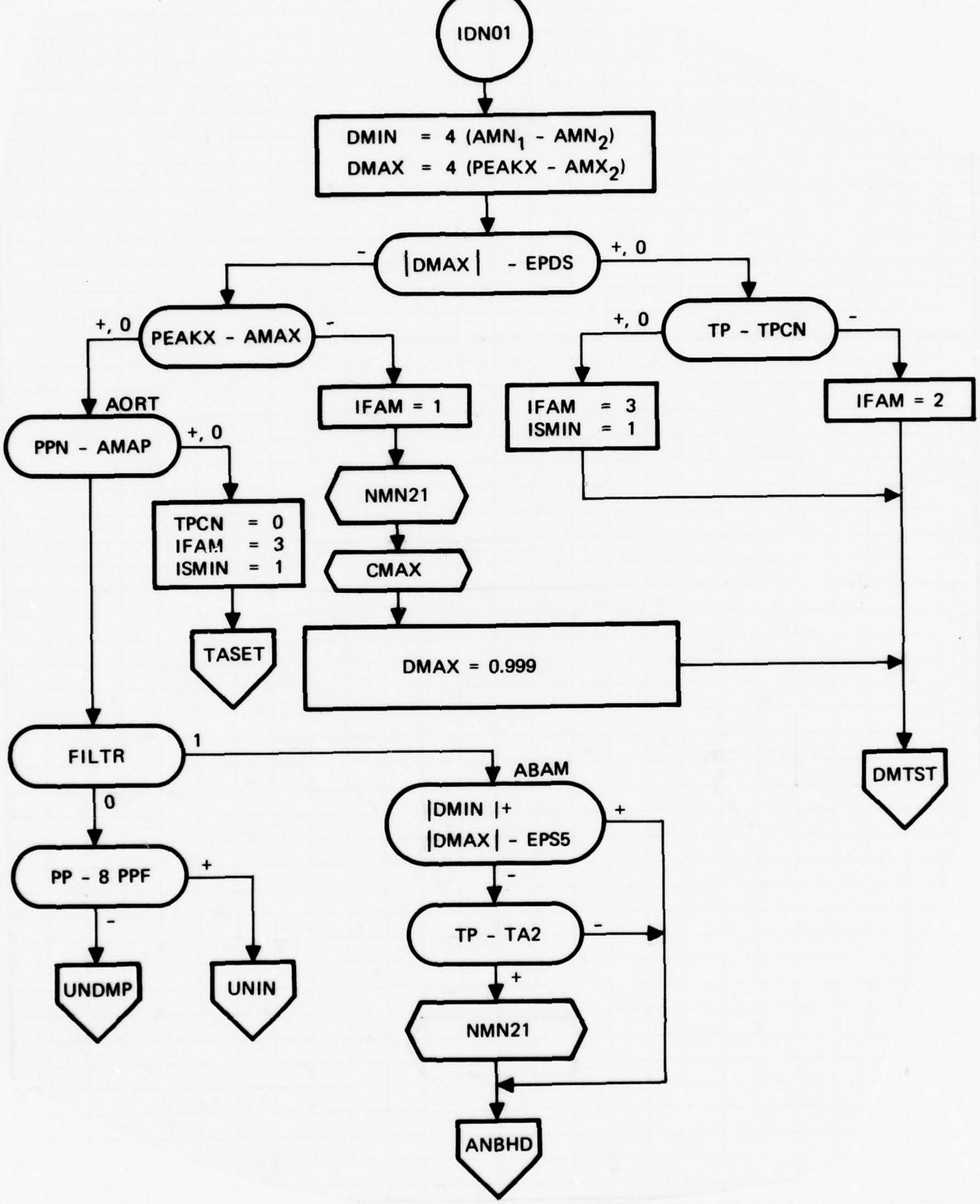

MINPT
PEAKN = AMPK
1, 5
IFAM
2,3,4,0
PEAKN - AMMAX - AMMAX + PEAKX
0, +
-
WDTST
SEQ - SEQWD
-
+, 0
NOEVT
THO = THO + { 0°: NMIN = 1 ; 180° : NMIN = 2 }
SEQN = SEQ - 5 - { LAG: FILTR = 0 ; ALAG: FILTR ≠ 0 }
K = NMIN
TP = SEQN - SEQN_K
FXTRP
IFRZ = -1.0
MINPT (CONT)

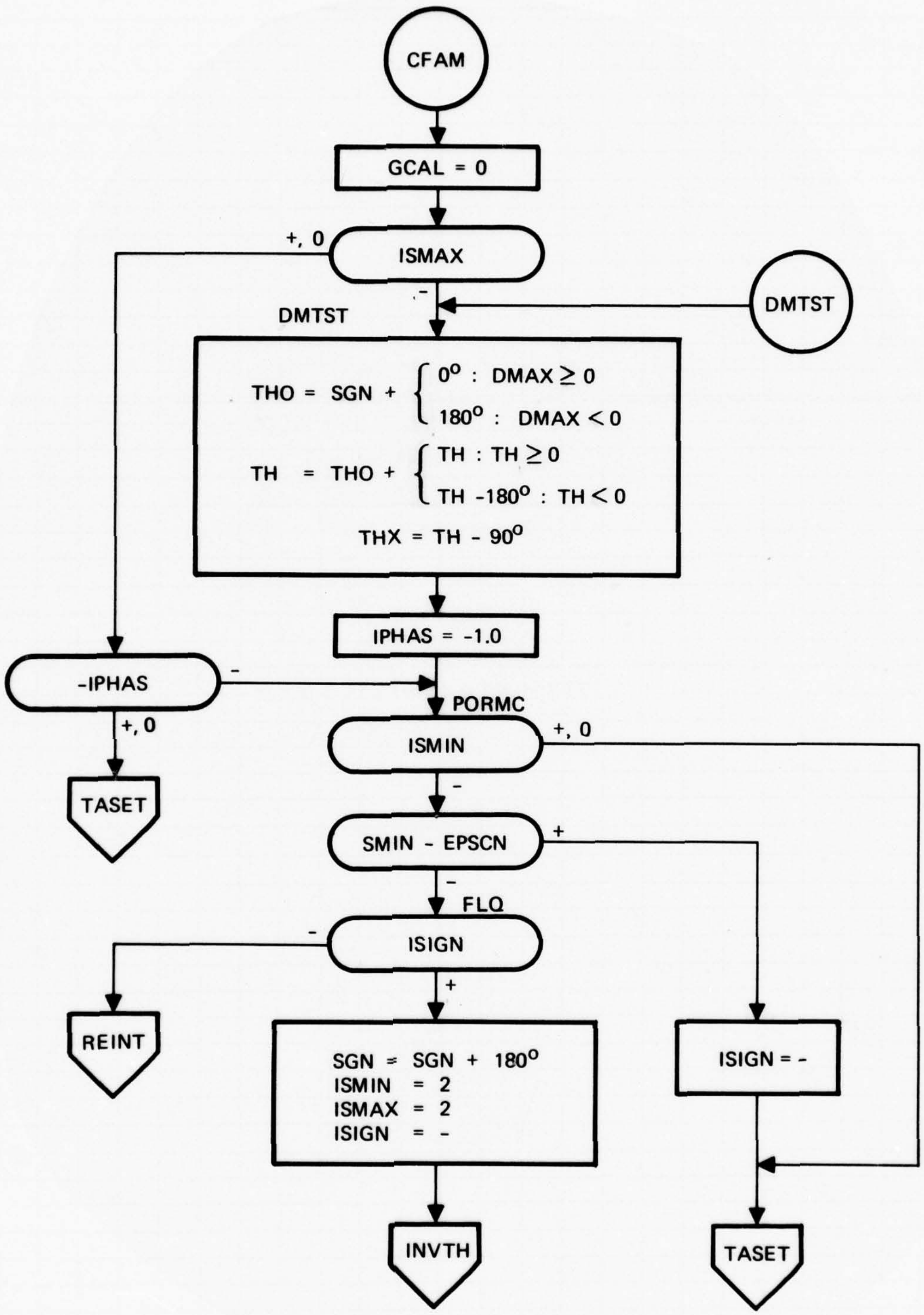

MINPT (CONT)
PP = PEAKX - PEAKN
PPN = PP/PEAKX
PPH = (PPN)1/2
K = NMIN
SMAX = PEAKX - AMXk
SMIN = PEAKN - AMNk
DMAX = AMX2 - 2 • AMX1 + PEAKX
SEQWD = SEQ + 5
SEQLT = SEQ + 8 • TC1
AMX2 = AMX1
AMX1 = PEAKX
AMN2 = AMN1
AMN1 = PEAKN
SEQN3 = SEQN2
SEQN2 = SEQN1
SEQN1 = SEQN
IFAM
≠ 0
= 0
IDENT
ISMIN
= 0
≠ 0
IDN01
ISMIN = ISMIN - 1
PACK

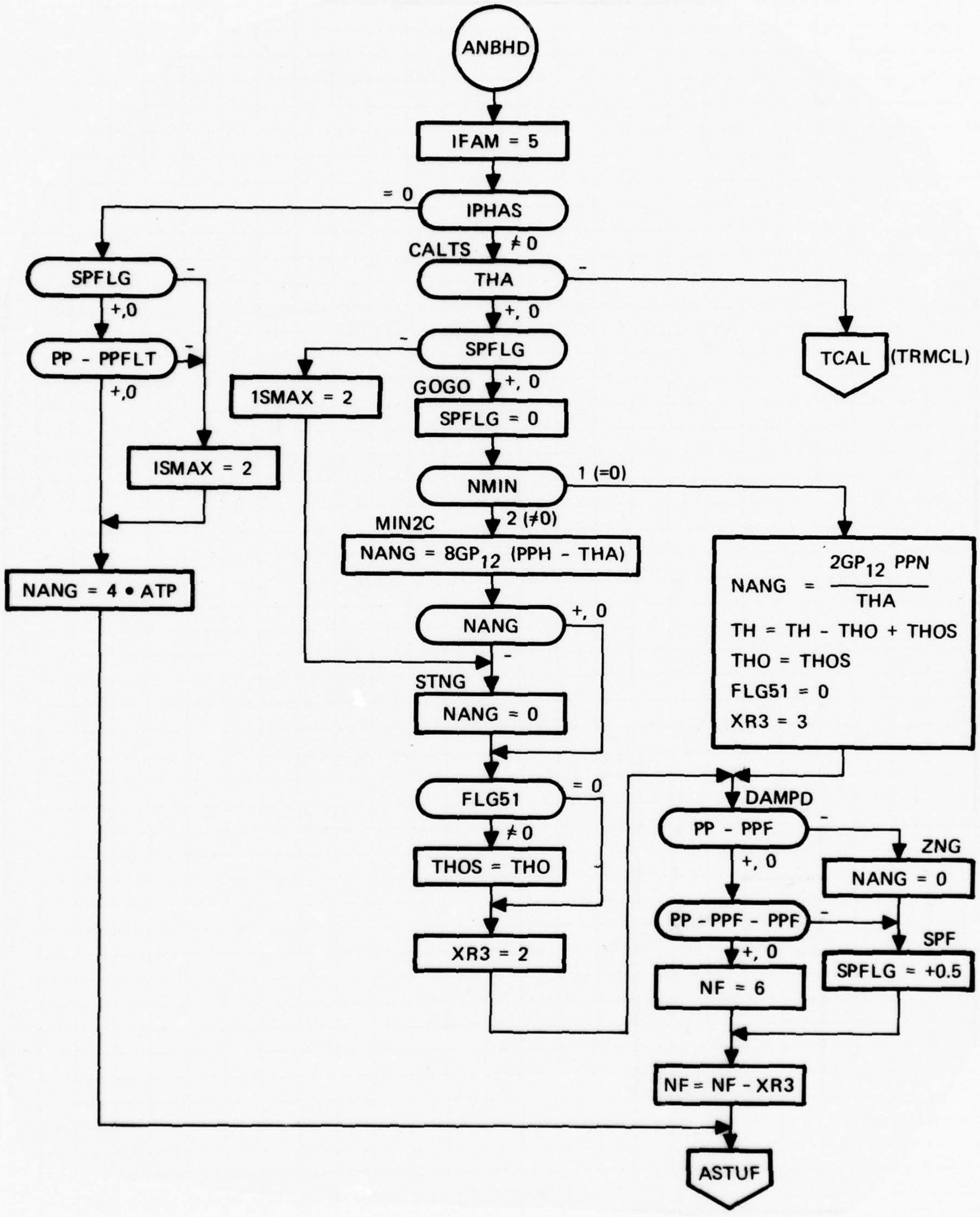

FXTRP
=5
IFAM
OTHER
=0
ATP = TP
TEMP = LIMIT (-TPD < TP - TPM < TPD)
FE = 2/(TEMP + TPM)
TH = THO + FE (SEQ - SEQN)
RTN


NMN21
NMIN = 1
SMAX = PEAKX - AMX2
SMIN = PEAKN - AMN2
THO = THO + 180°
TP = SEQN - SEQN2
FXTRP
RTN

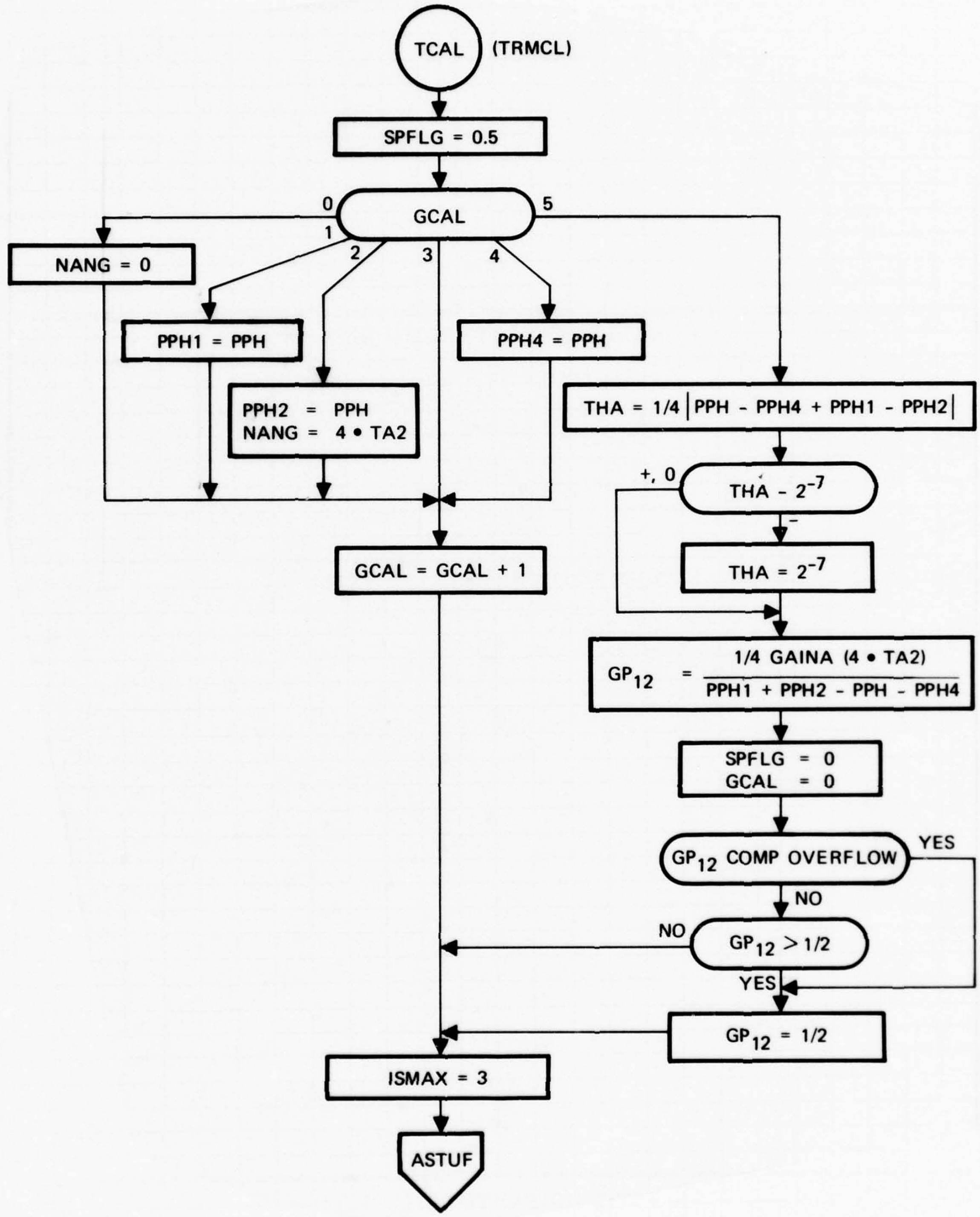

IDENT
NMIN
(=0) = 1
= 2 (≠0)
NMIN2
PEAKX - AMAX
MAXGD
+, 0
ISMAX
TST21
TP - TA2
NMN21
TPCN = TPCO
FAMTS
IFAM
4,5
1,2,3
|DMAX| - EPDS
NMINI
DMAX = 0.999
BGTST
PPN - AMAP
CNTST
TP - TPCN
TP - TPA
IFAM = 2
IFAM = 3
NMIN = 2
THO = THO + 180°
TP = SEQN - SEQN3
TCLTS
SPFLG
ANTST
PEAKN - AMAX
TP - TA1
FXTRP
ANBHD
NANG = 0
(SMIN - SMAX/4) SMAX
IFAM = 3
TPCN = 0
IFAM = 4
≠2
IFAM
= 2
ISIGN
ASTUF
IFAM = 3
ISMIN = 2
SMIN = 0.999
SMIN = SMAX
CMAXC
(SUBROUTINE)
PACK
IFAM = 1
i = NMIN
CMAX = AMXi - 1/2(AMXi - PEAKN)
CFAM

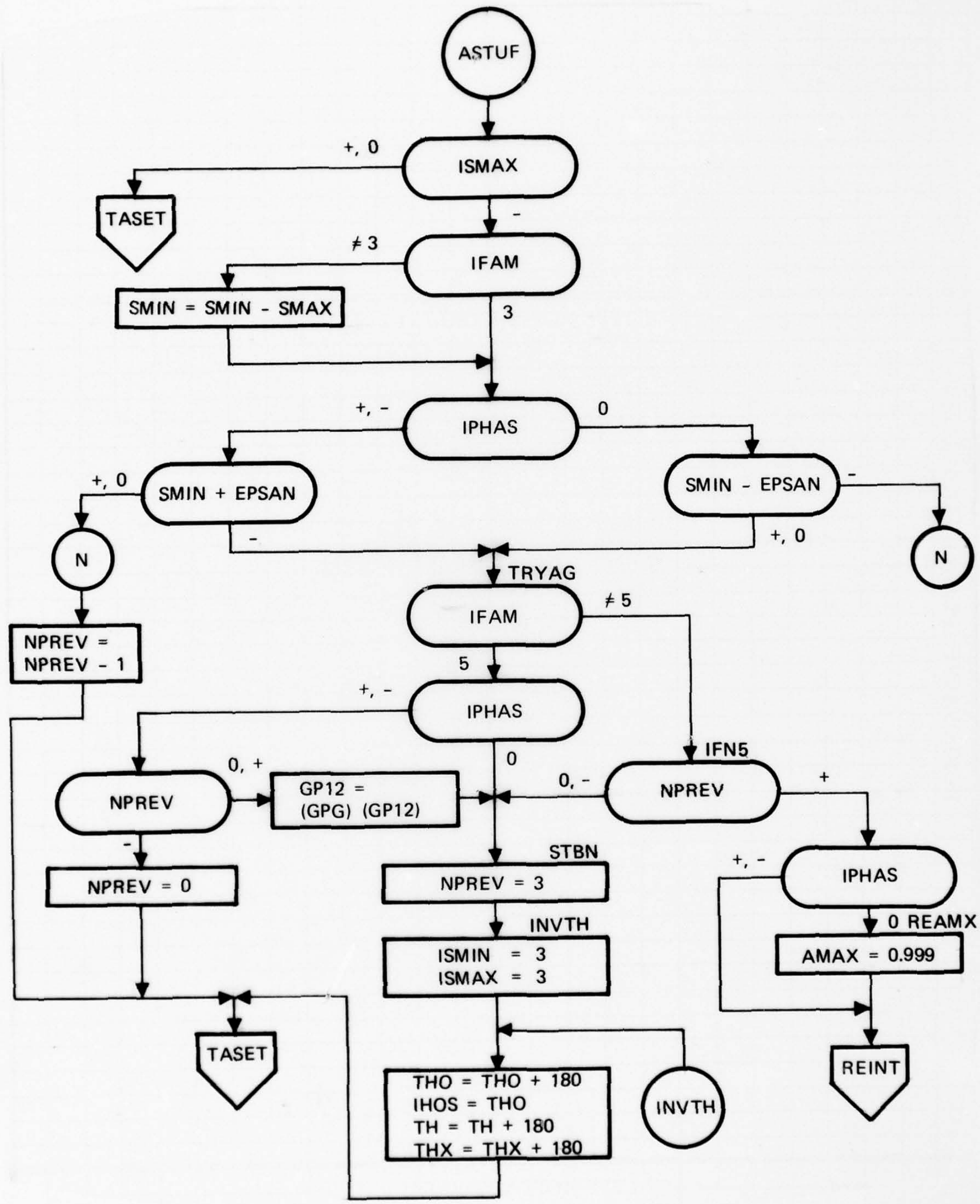

IDN01
DMIN = 4 (AMN1 - AMN2)
DMAX = 4 (PEAKX - AMX2)
|DMAX| - EPDS
-
+, 0
PEAKX - AMAX
+, 0
-
TP - TPCN
+, 0
-
AORT
PPN - AMAP
+, 0
IFAM = 1
IFAM = 3
ISMIN = 1
IFAM = 2
NMN21
TPCN = 0
IFAM = 3
ISMIN = 1
CMAX
TASET
DMAX = 0.999
FILTR
1
0
ABAM
|DMIN |+
|DMAX| - EPS5
+
DMTST
PP - 8 PPF
+
-
-
TP - TA2
-
+
UNDMP
UNIN
NMN21
ANBHD

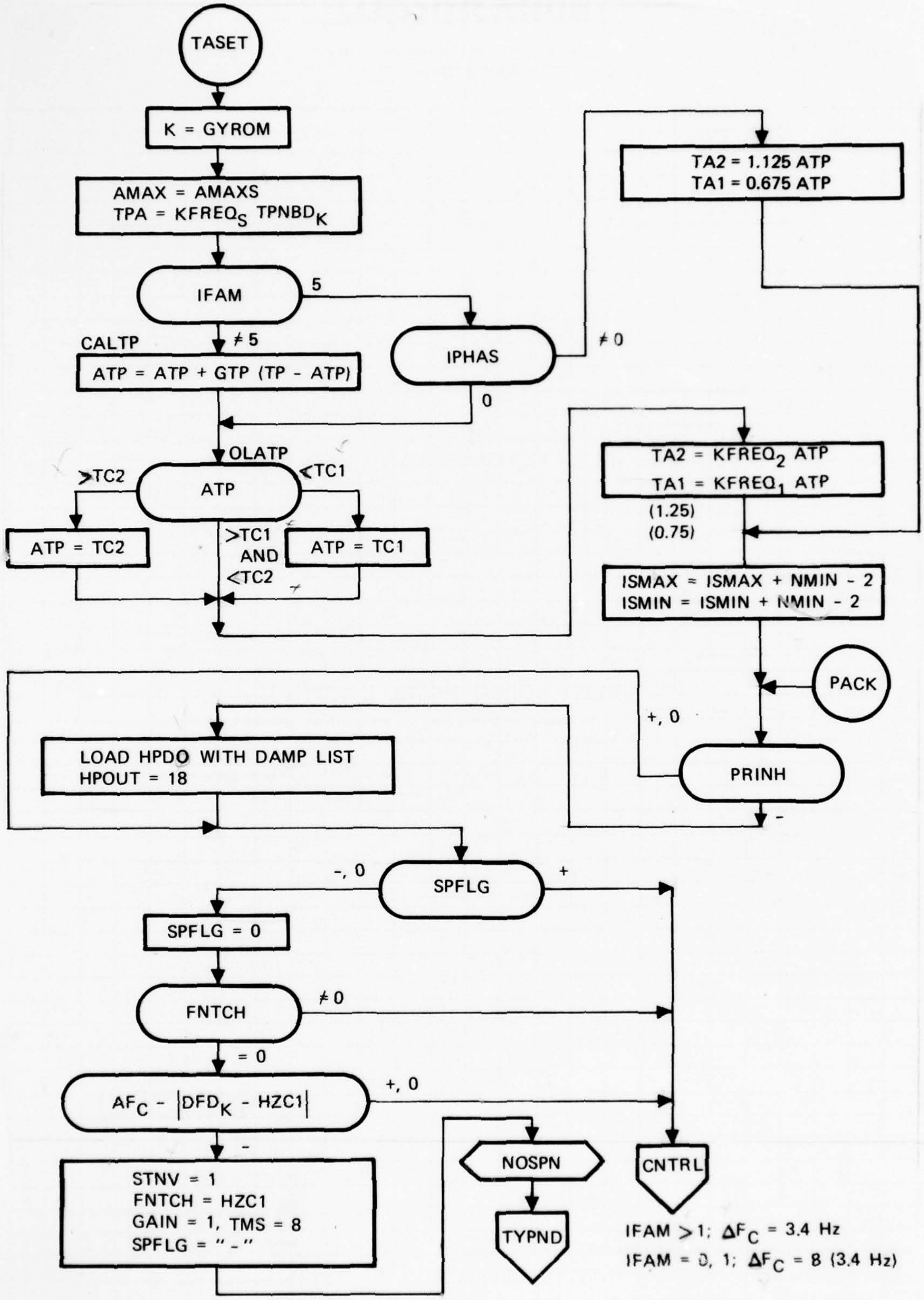

CFAM
GCAL = 0
+, 0
ISMAX
-
DMTST
DMTST
THO = SGN + { 0° : DMAX ≥ 0 ; 180° : DMAX < 0 }
TH = THO + { TH : TH ≥ 0 ; TH -180° : TH < 0 }
THX = TH - 90°
IPHAS = -1.0
-IPHAS
-
+, 0
TASET
PORMC
ISMIN
+, 0
-
SMIN - EPSCN
+
-
FLQ
ISIGN
-
+
REINT
SGN = SGN + 180°
ISMIN = 2
ISMAX = 2
ISIGN = -
ISIGN = -
INVTH
TASET

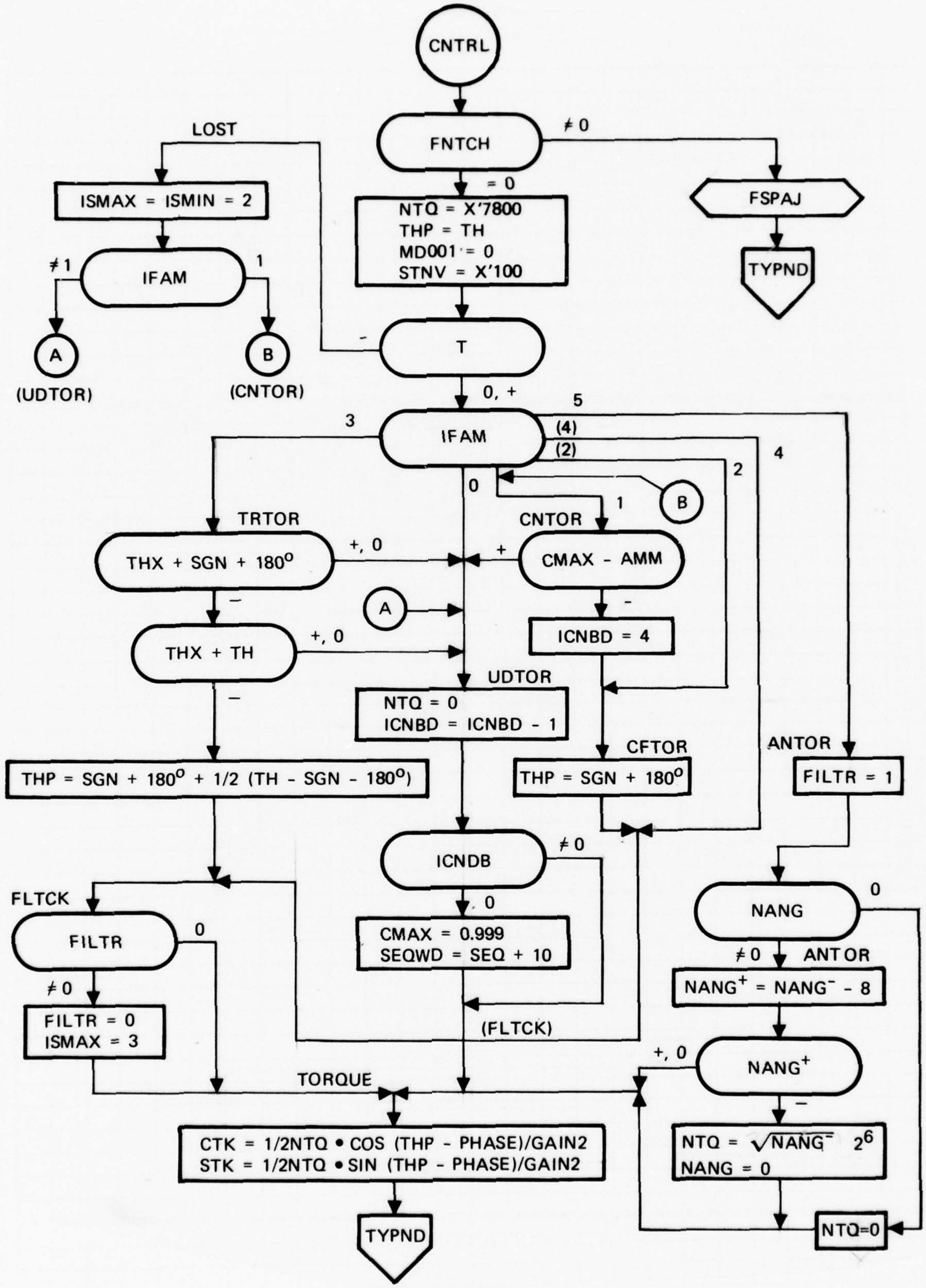


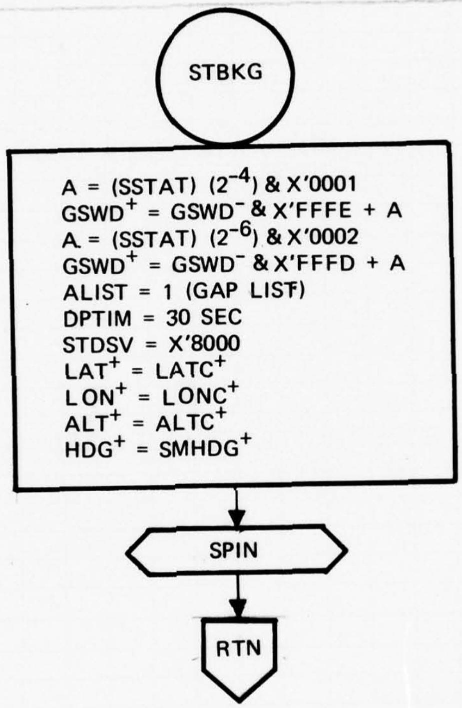
ANBHD
IFAM = 5
= 0
IPHAS
CALTS
≠ 0
THA
-
+, 0
TCAL
(TRMCL)
SPFLG
-
+,0
PP - PPFLT
-
+,0
ISMAX = 2
SPFLG
-
1SMAX = 2
GOGO
+, 0
SPFLG = 0
NMIN
1 (=0)
MIN2C
2 (≠0)
NANG = 8GP12 (PPH - THA)
NANG = 2GP12 PPN / THA
TH = TH - THO + THOS
THO = THOS
FLG51 = 0
XR3 = 3
NANG = 4 • ATP
NANG
+, 0
-
STNG
NANG = 0
FLG51
= 0
≠ 0
THOS = THO
XR3 = 2
DAMPD
PP - PPF
-
ZNG
+, 0
NANG = 0
PP - PPF - PPF
-
SPF
+, 0
NF = 6
SPFLG = +0.5
NF = NF - XR3
ASTUF

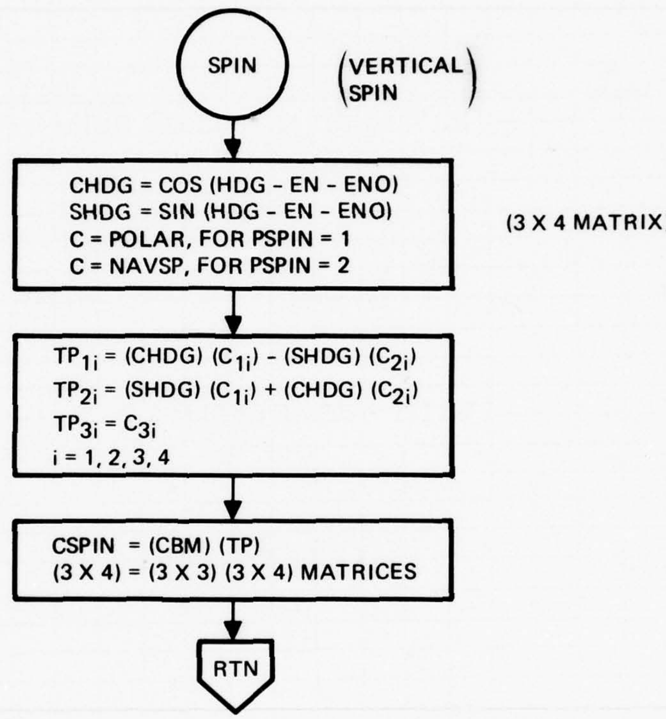

TCAL
(TRMCL)
SPFLG = 0.5
GCAL
0
1
2
3
4
5
NANG = 0
PPH1 = PPH
PPH2 = PPH
NANG = 4 • TA2
PPH4 = PPH
THA = 1/4 |PPH - PPH4 + PPH1 - PPH2|
+, 0
THA - 2^-7
–
THA = 2^-7
GCAL = GCAL + 1
GP12 = 1/4 GAINA (4 • TA2) / PPH1 + PPH2 - PPH - PPH4
SPFLG = 0
GCAL = 0
GP12 COMP OVERFLOW
YES
NO
NO
GP12 > 1/2
YES
GP12 = 1/2
ISMAX = 3
ASTUF


ASTUF
ISMAX
+, 0
TASET
-
IFAM
≠ 3
SMIN = SMIN - SMAX
3
IPHAS
+, -
0
SMIN + EPSAN
+, 0
-
SMIN - EPSAN
-
+, 0
N
N
TRYAG
IFAM
≠ 5
NPREV = NPREV - 1
5
IPHAS
+, -
0
IFN5
NPREV
0, +
GP12 = (GPG) (GP12)
0, -
NPREV
+
-
NPREV = 0
STBN
NPREV = 3
IPHAS
+, -
INVTH
ISMIN = 3
ISMAX = 3
0 REAMX
AMAX = 0.999
TASET
THO = THO + 180
IHOS = THO
TH = TH + 180
THX = THX + 180
INVTH
REINT


TASET
K = GYROM
AMAX = AMAXS
TPA = KFREQ_S TPNBD_K
IFAM
5
≠5
CALTP
ATP = ATP + GTP (TP - ATP)
IPHAS
≠0
0
TA2 = 1.125 ATP
TA1 = 0.675 ATP
OLATP
ATP
>TC2
<TC1
ATP = TC2
>TC1 AND <TC2
ATP = TC1
TA2 = KFREQ_2 ATP
TA1 = KFREQ_1 ATP
(1.25)
(0.75)
ISMAX = ISMAX + NMIN - 2
ISMIN = ISMIN + NMIN - 2
PACK
+, 0
LOAD HPDO WITH DAMP LIST
HPOUT = 18
PRINH
-
SPFLG
-, 0
+
SPFLG = 0
FNTCH
≠0
= 0
AF_C - |DFD_K - HZC1|
+, 0
-
STNV = 1
FNTCH = HZC1
GAIN = 1, TMS = 8
SPFLG = "-"
NOSPN
TYPND
CNTRL
IFAM > 1; ΔF_C = 3.4 Hz
IFAM = 0, 1; ΔF_C = 8 (3.4 Hz)


CNTRL
FNTCH
≠ 0
= 0
FSPAJ
TYPND
LOST
ISMAX = ISMIN = 2
NTQ = X'7800
THP = TH
MD001 = 0
STNV = X'100
≠ 1
IFAM
1
A
B
(UDTOR)
(CNTOR)
T
0, +
5
3
IFAM
(4)
(2)
2
4
0
1
B
TRTOR
CNTOR
THX + SGN + 180°
+, 0
+
CMAX - AMM
A
THX + TH
+, 0
ICNBD = 4
UDTOR
NTQ = 0
ICNBD = ICNBD - 1
CFTOR
ANTOR
THP = SGN + 180° + 1/2 (TH - SGN - 180°)
THP = SGN + 180°
FILTR = 1
ICNDB
≠ 0
0
NANG
FLTCK
FILTR
0
CMAX = 0.999
SEQWD = SEQ + 10
≠ 0
ANTOR
≠ 0
NANG+ = NANG- - 8
FILTR = 0
ISMAX = 3
(FLTCK)
+, 0
NANG+
TORQUE
CTK = 1/2NTQ • COS (THP - PHASE)/GAIN2
STK = 1/2NTQ • SIN (THP - PHASE)/GAIN2
NTQ = √NANG- 2^6
NANG = 0
TYPND
NTQ=0


STBKG
A = (SSTAT) (2^{-4}) & X'0001
$GSWD^+$ = $GSWD^-$ & X'FFFE + A
A = (SSTAT) (2^{-6}) & X'0002
$GSWD^+$ = $GSWD^-$ & X'FFFD + A
ALIST = 1 (GAP LIST)
DPTIM = 30 SEC
STDSV = X'8000
LAT^+ = $LATC^+$
LON^+ = $LONC^+$
ALT^+ = $ALTC^+$
HDG^+ = $SMHDG^+$
SPIN
RTN



SPIN
(VERTICAL SPIN)
CHDG = COS (HDG - EN - ENO)
SHDG = SIN (HDG - EN - ENO)
C = POLAR, FOR PSPIN = 1
C = NAVSP, FOR PSPIN = 2
(3 X 4 MATRIX)
TP_{1i} = (CHDG) (C_{1i}) - (SHDG) (C_{2i})
TP_{2i} = (SHDG) (C_{1i}) + (CHDG) (C_{2i})
TP_{3i} = C_{3i}
i = 1, 2, 3, 4
CSPIN = (CBM) (TP)
(3 X 4) = (3 X 3) (3 X 4) MATRICES
RTN

TABLE I-2. START PROGRAM VARIABLES

Symbol	Index i	Index j	Description	Max Value	Word Length (Bits)
TCI	– (Automatic Sequence 1–15 if Sign Bit is Set)	–	Start Mode (See Table I-1)	–	16
TCI′	–	–	TCI with Sign Bit Set 0	–	16
SMFLG	–	–	First Time Flag (= 0) and Sequence Counter in Mode	–	16
JUMPR	–	–	Starting Address of Mode Specified by TCI. Also Termination Flag (JUMPR = 0)	–	16
TSFLG	–	–	Positioning Routine Flag	–	16
CSPNP	–	–	Spinup Direction Pointer (CSPIN) (Values 0, 1, 2)	–	16
GYROM	–	–	Gyro Pointer (1, 2)	–	16
BUTIM	–	–	Mode Time Limit	–	16

TABLE I-2. (Cont)

Symbol	Index i	Index j	Description	Max Value	Word Length (Bits)
PFLAG	–	–	Print Flag	–	16
FNTCH	–	–	Speed Adjust Routine Freq Goal (0 = Speed Adjust Complete)	1302.08 Hz	16
SPEND	–	–	Charge Monitor Recycle Counter	–	16
POINT	–	–	Address of Charge Monitor Subroutines	–	16
ZTIME	–	–	High Current Z Heat Timer	2^9 Sec	16
PHICG	–	–	Charge Monitor Fourier Analysis Phase	π Rad	16
CCGB, SCGB	–	–	Cos and Sin Fourier Coefficients	5	16
$CHARG_i$	Gyro (1, 2)	–	Charge on Rotor/Large Charge Limit	100	16
TMS	–	–	Speed Adjust Routine Timer	2^{15} Cycles	16
GAIN	–	–	Speed Adjust Routine Torquing Gain	1	16
FSPIN	–	–	Spin Routine – Rotor Speed Goal	1302.08 Hz	16
FSMC	–	–	Spin Routine – Initial Motor Frequency	1302.08 Hz	16
MFSMC	–	–	Spin Routine – Max Motor Frequency	1302.08 Hz	16
DFSMC	–	–	Spin Routine – Motor Freq Charge/Cycle	1302.08 Hz	16
DELTA	–	–	Speed Detect Routine – MUM Freq Jitter	1302.08 Hz	16
KT	–	–	Speed Detect Routine – MUM Threshold Gain	1	16

TABLE I-2. (Cont)

Symbol	Index i	Index j	Description	Max Value	Word Length (Bits)
U	–	–	Speed Adjust Routine – Spin Direction	–	16
AMM0, AMM1, AMM2, AMM3	–	–	Speed Detect – MUM Magnitudes	1	16
SVDM	–	–	Speed Detect – Previous Demod Freq	1302.08 Hz	16
$THRM_i$	Gyro (1, 2)		Thermal Gradient Model – Gyro	167 μ in.	32
AXD, AYD, AZD BXD, BYD, BZD SXD, SYD, SZD	–	–	Spin Motor Outputs in Gyro Coordinates (Also AXD_i, i = 0, 1, 2, - - - 11)	1	16
SSTAT	–	–	Start Mode Status Bit (16-TCI') Set When Mode Complete	–	16
$CSPIN_{ij}$	(1, 2, 3)	(1, 2, 3, 4)	Spin and Degauss Matrix	1	16
THRME	–	–	Temp Stat. Routine – Thermal Gradient Model – EMA	312.5°F	32
PSPIN	–	–	Polar Spin Flag (1 = Polar Spin, 0 = Nov Spin)	–	–

TABLE I-2. (Cont)

Symbol	Index i	Index j	Description	Max Value	Word Length (Bits)
IFAM	–	–	Polhode Family (Region) 0 – Unidentified 1 – C Nbhd 2 – C Family 3 – Transition Zone 4 – A Family 5 – A Nbhd	–	16
SGN	–	–	C Family Sign (0, π)	π Rad	16
ISIGN	–	–	C Family Sign Has Been Determined (-1)	–	16
IPHAS	–	–	+A Family Identified (-1) (Not Identified = 0)	–	16
NMIN	–	–	Number of Min Per Polhode Period (1, 2)	–	16
SPFLG	–	–	Spin Flag 0 – No Speed Adjust - – Speed Adjust in Progress + – Inhibit Speed Adjust	–	16
IFRZ	–	–	TH Extropolation Flag 0 – Do Not Extrapolate - – Extrapolate + – Do Not Extrapolate and Check Max Threshold	–	16
NPREV	–	–	Counter to Detect Successive Phase Reversals	–	16

TABLE I-2. (Cont)

Symbol	Index i	Index j	Definition	Max Value	Word Length (Bits)
AMM	–	–	Smoothed MUM Magnitude	1	32
AMS_i	Filter Stages (1, 2, 3)	–	MUM Magnitude Filter Outputs	1	32
SEQUN	–	–	SEQ Threshold – Undamp Torque	2^{15}	16
SEQLT	–	–	SEQ Threshold – No Minimum	2^{15}	16
SEQWD	–	–	SEQ Threshold – Minimum Time for Next Min	2^{15}	16
NF	–	–	Damping Complete Counter (-1)	–	–
XR3	–	–	Decrement NF	–	–
$AMMS_i$	(0,1, - -, 11)		AMM Data Storage for Max/Min Filter (AMM_{11} = -1)	1	32
PNTR	–	–	Pointer for AMMS List	–	–
D1	–	–	$2^{-9} \sum_{i=-5}^{5} AMMS_{i+6}$	1	32
D2	–	–	$2^{-9} \sum_{i=-5}^{5} i\, AMMS_{i+6}$	1	32
D3	–	–	$\sum_{i=-5}^{5} i^2 (2^{-9} AMMS_{i+6} - D1/11)$	1	32
AMPK	–	–	Amplitude of Max or Min	1	32
PEAKN	–	–	Amplitude of Min Point	1	32
PEAKX	–	–	Amplitude of Max Point	1	32
TH	–	–	Phase Variable	π Rad	16

TABLE I-2. (Cont)

Symbol	Index i	Index j	Definition	Max Value	Word Length (Bits)
THX	–	–	Value of TH at Last Max Threshold Point	π Rad	16
THO	–	–	Cardinal Value at Last Min Point $(0, \pi)$	π Rad	16
FE	–	–	Extrapolation Frequency for TH	π Rad/Cycle	16
TP	–	–	Polhode Period	2^{15} Cycles	16
AMMAX	–	–	Max Threshold Value	1	16
AMX_i	(1, 2)	–	Past Values of PEAKX (2 = Oldest)	1	16
AMN_i	(1, 2)	–	Past Values of PEAKN (2 = Oldest)	1	16
SEQN, $SEQN_i$	(1, 2, 3)	–	Past Values of Time of Min (3 = Oldest) (SEQN = Current Min)	2^{15} Cycles	16
PP	–	–	Peak to Peak Amplitude (PEAKX - PEAKN)	1	32
PPN	–	–	*Normalized* PP (PP/PEAKX)	1	32
PPH	–	–	$PPN^{1/2}$	1	16
SMAX	–	–	Slope of Max Amplitudes	1	16
SMIN	–	–	Slope of Min Amplitudes	1	16
DMAX	–	–	Difference Between High and Low Max	1	16
ISMAX	–	–	Data Invalid When Positive	–	16
ISMIN	–	–	Data Invalid When Positive	–	16
TA_i	(1, 2)	–	TP Threshold When NMIN = 1, 2	2^{15} Cycles	16

TABLE I-2. (Cont)

Symbol	Index i	Index j	Definition	Max Value	Word Length (Bits)
TC_i	(1, 2)	–	ATP Limits ($TC1 \leq ATP \leq TC2$)	2^{15} Cycles	16
ATP	–	–	Smoothed TP	2^{15} Cycles	16
NANG	–	–	Control Angles ANBHD	2^{15} Torque Units	16
CMAX	–	–	AMM Threshold for CNBHD Control	1	16
GCAL	–	–	ANBHDCal Sequence Counter	–	16
FLAG51	–	–	Indicates First Entry into NMIN = 1 in ANBHD with IPHAS = -1	–	16
THOS	–	–	THO Value in ANBHD, NMIN = 1	π Rad	16
THA	–	–	A Pendulosity Component	1 Rad	16
GP_{12}	–	–	ANBHD Control Gain	2^{12} Torque Units	16
THP	–	–	Torque Control Angle	π Rad	16
ICNBD	–	–	CNBHD Control Flag - Control in Progress 0 Reset	–	16
NTQ	–	–	Torque Amplitude (Current)	1	16
PPH_i	(1, 2, 4)	–	PPH Storage for ANBHD Cal	1	16
AMAX	–	–	Family Identification Threshold	1	16
TPA	–	–	Transition Zone TP Threshold – A Family Side	2^{15} Cycles	16
TPC	–	–	Transition Zone TP Threshold – C Family Side	2^{15} Cycles	16

TABLE I-2. (Concluded)

Symbol	Index		Definition	Max Value	Word Length
	i	j			
DEMF	–	–	Demod Routine Mode	–	16
SPINF	–	–	Holds Demod Routine in Freq Lock Mode IF $\neq 0$; Normal Mode Sequencing IF = 0	–	16
RTIME	–	–	1 Sec Clock	2^{15} Sec	16
BATST	–	–	= 0, Do Not Perform Battery Test = 1, Do Perform Battery Test (Load "1", Keyin "0")	–	16

TABLE I-3. START PROGRAM CONSTANTS

Symbol	Definition	Value	Max Value	Scaled Value
$TIME_i$	Time Limit of i^{th} Mode, i = TXP	(1) 1805 Sec	2^{15} Sec	–
		(2) 3.5 Min		
		(3) 120 Sec		
		(4) 3 Sec		
		(5) 40 Sec		
		(6) 3 Sec		
		(7) 15 Sec		
		(8) 60 Sec		
		(9) 15 Sec		
		(10) 15 Sec		
		(11) 60 Sec		
		(12) 15 Sec		
		(13) 5 Min		
		(14) 3 Sec		
		(15) 3 Sec		
DLGZ	Z Heat Gap Threshold	34 μ in	167.9 μ In.	0.2025
GCNTZ	High Current Z Heat Predicted Gap Heating Rate	3 μ In./Sec	671.7 μ In./2^{-6} Sec	0.000070
ZCAS	Z Heat Minimum Case Temp for Termination	15^{o}F	521^{o}F	0.02879
DFCG	Demod Slip Frequency During Charge Monitor	6.35782 Hz	1302.08 Hz	0.00488
DLPCG	Demod Slip Phase Increment During Charge Monitor (2^{-6} Sec) (DFCG)	35.76274^{o}	π Rad	0.1986819
CGSL	Charge Monitor Large Charge Threshold BITE	0.116	1	0.116
DDGZ	Z Heat Threshold	2 μ In.	671.7 μ In.	0.00298

TABLE I-3. (Cont)

Symbol	Definition	Value	Max Value	Scaled Value
GTH	Thermal Transient Decay Gain			
	(Getter Gyros)	$2^{-6}/40.0$	1	$3.9\backslash^{-4}$
	(VACION Pump Gyros)	2^{-6}Sec/18.4 Sec	1	$8.5\backslash^{-4}$
KU	Rotor Temp Uncertainty Factor	$\frac{1}{0.5\,\mu \text{in.}/(^{\circ}\text{F})^2}$	$(521^{\circ}\text{F})^2/167.9\,\mu$in.	0.001237
GAPT	Temp Stabilization Complete Threshold	0.5 μ in.	167.9 μin.	0.00298
GCNTS	Temp Stabilization Predicted Gap Heating Rate	0.5 μ in./Sec	(167.9)(64) μin./Sec	$0.465\backslash^{-4}$
DFSPN	Speed Adjust Routine – Termination Mode Threshold	1.9 Hz	1302.08 Hz	0.00146
DFADJ	Speed Adjust Routine Predicted Spinup Rate	5 Hz/Cycle	1302.08 Hz/Cycle	0.0039
ETH	EMA Thermal Time Constant	1/(64) (32)	1	2^{-11}
FHEMA	EMA Fast Heating Rate	50°F/Min	(66)(64) 312.5°F/Min	$0.416\backslash^{-4}$
TSPND	Safe Charge Amp Temp for Suspension	10°F	312.5°F	0.032
UPGZ	Suspended Z Heat Limit	17 μin.	167.9 μ in.	0.101
UPDGZ	Suspended Z Heat – Heating Rate	2.2μin./Sec	(167.9) μ in./Sec	$2.047\backslash^{-4}$
AT	Speed Detect Routine AMMO Threshold	-2^{-4}	1	-2^{-4}

TABLE I-3. (Cont)

Symbol	Definition	Value	Max Value	Scaled Value
V40	EMA Precounter BITE Test Pulse Count	–	2^9 Pulse	XA500
DV40	EMA Precounter BITE Test Pulse Variance	2 Pulse	2^9 Pulse	2^{-8}
THPOS	Rotor Positioning BITE Threshold (6°)	0.01	1	0.01
FHCNT	Fast Heater Gap Expansion Rate (80°F/Min) (0.467 μ in./°F)	0.623 μ in./Sec	(167.9)(64)μin./Sec	0.579 $^{-4}$
PPF	Damp – Termination Threshold	0.0007	1	0.0007
PPFLT	Damp – Inhibit Phase Reversal Threshold	0.01	1	0.01
AMAP	Damp – PPN Threshold for ANBHD	0.04	1	0.04
GPG	GP_{12} Reduction Factor in Case of Phase Loss	0.8	1	0.8
GTP	ATP Filter Gain	0.3935	1	0.3935
GAIN A	ANBHD Gain	0.7	1	0.7
GAIN1	SMC Electronics Gain (DC/2nd Harmonic)	0.7	1	0.7
GAIN2	SMC Electronics Gain (Fundamental/2nd Harmonic)	0.805/0.94	1	0.856

TABLE I-3. (Cont)

Symbol	Definition	Value	Max Value	Scaled Value
GN1	MUM Magnitude Filter Gain (Light)	2^{-1}	1	2^{-1}
GN2	MUM Magnitude Filter Gain (Heavy)	2^{-2}	1	2^{-2}
Lag	Lag Introduced by Light Filter	2 Cycle	2^{15} Cycle	2^{-14}
ALAG	Lag Introduced by Heavy Filter	7 Cycle	2^{15} Cycle	2.136\ -4
AMAXS	Family Identification MUM Mag Threshold (AMAX)	0.72	1	0.72
EPDS	DMAX Threshold – Detect DMAX $\neq 0$ (0.025)	0.040	1	0.040
EPDMS	DMAX Threshold – Detect DMAX = 0	0.004	1	0.004
EPSCN	SMIN Threshold – $\pm$ C Family Detect	0.001	1	0.001
EPSAN	SMIN Threshold – A Family Phase Reverse	0.001	1	0.001
EPS5	DMIN Threshold – ANBHD NMIN 1, 2 Test	0.001	1	0.001
$KFREQ_1$	*TA1 Factor*	0.75	2^3	0.09375
$KFREQ_2$	TA2 Factor	1.25	2^3	0.15625
$KFREQ_3$	TC1 Factor	0.5	2^3	0.0625
$KFREQ_4$	TC2 Factor	1.25	2^3	0.15625
$KFREQ_5$	TPA Factor	1.5	2^3	0.1875
$KFREQ_6$	TPC Factor	1.3	2^3	0.1625
TPO	TP Max Threshold	128 Cycles	2^{15}	2^{-8}

TABLE I-3. (Cont)

Symbol	Definition	Value	Max Value	Scaled Value
POLAR	Polar Spin Up Matrix (3 X 4)	0.0	1	0.0
	Scaled $(1 - 2^{-4})$	0.9375	1	0.9375
		0.0	1	0.0
		-0.522252	1	-0.522252
		0.0		0.0
		0.778566	1	0.778566
		0.0	1	0.0
		-0.9375	1	-0.9375
		0.0	1	0.0
		0.778566	1	0.778566
		0.0		0.0
		0.522253	1	0.522253
NAVSP	Nav Spin Up Matrix (3 X 4)	0.722468	1	0.722468
	Scaled $(1 - 2^{-4})$	-0.580936	1	-0.580936
		-0.139536	1	-0.139536
		0.597280	1	0.597280
		0.707694	1	0.707694
		0.146130	1	0.146130
		0.014779	1	0.014779
		-0.201506	1	-0.201506
		0.915475	1	0.915475
		0.722468	1	0.722468
		-0.580936	1	-0.580936
		-0.139536	1	-0.139536

TABLE I-3. (Concluded)

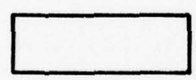
Symbol	Definition	Value	Max Value	Scaled Value
V24	Nominal Voltage Magnitude	24	30	0.8
V15	Nominal Voltage Magnitude	15	30	0.5
V7	Nominal Voltage Magnitude	7.5	10	0.75
V5	Nominal Voltage Magnitude	5.2	10	0.52
V12	Nominal Voltage Magnitude	12	30	0.4
P15	Fractional Tolerance	0.15	1	0.15
P40	Fractional Tolerance	0.40	1	0.40
P10	Fractional Tolerance	0.10	1	0.10
P20	Fractional Tolerance	0.20	1	0.20
P025	Fractional Tolerance	0.025	1	0.025
P039	Fractional Tolerance	0.039	1	0.039
P02	Fractional Tolerance	0.02	1	0.02
SSTIM	Sure Start Time Interval Count	1 Sec	–	X'40
TCHRG	Battery Fast Charge Timer	1800 Sec	–	X'708
FCBAT	Battery Temp Limit During Fast Charge	70°F	312.5°F	0.224
TLG	Gyro Case Fast Warmup Threshold	-2°F	521°F	-0.00384
TLCA	Charge Amp Fast Warmup Threshold	-2°F	312.5°F	-0.0064
TLS	SEU Fast Warmup Threshold	-2°F	312.5°F	-0.0064
TLEMA	EMA Fast Warmup Threshold	-2°F	312.5°F	-0.0064

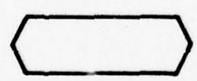
APPENDIX J

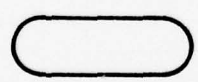
CALIBRATION DATA COLLECT PROGRAM
DETAILED FLOW CHARTS

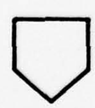
FLOW CHART SYMBOLS

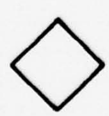

ENTRY POINT OR CONNECTOR

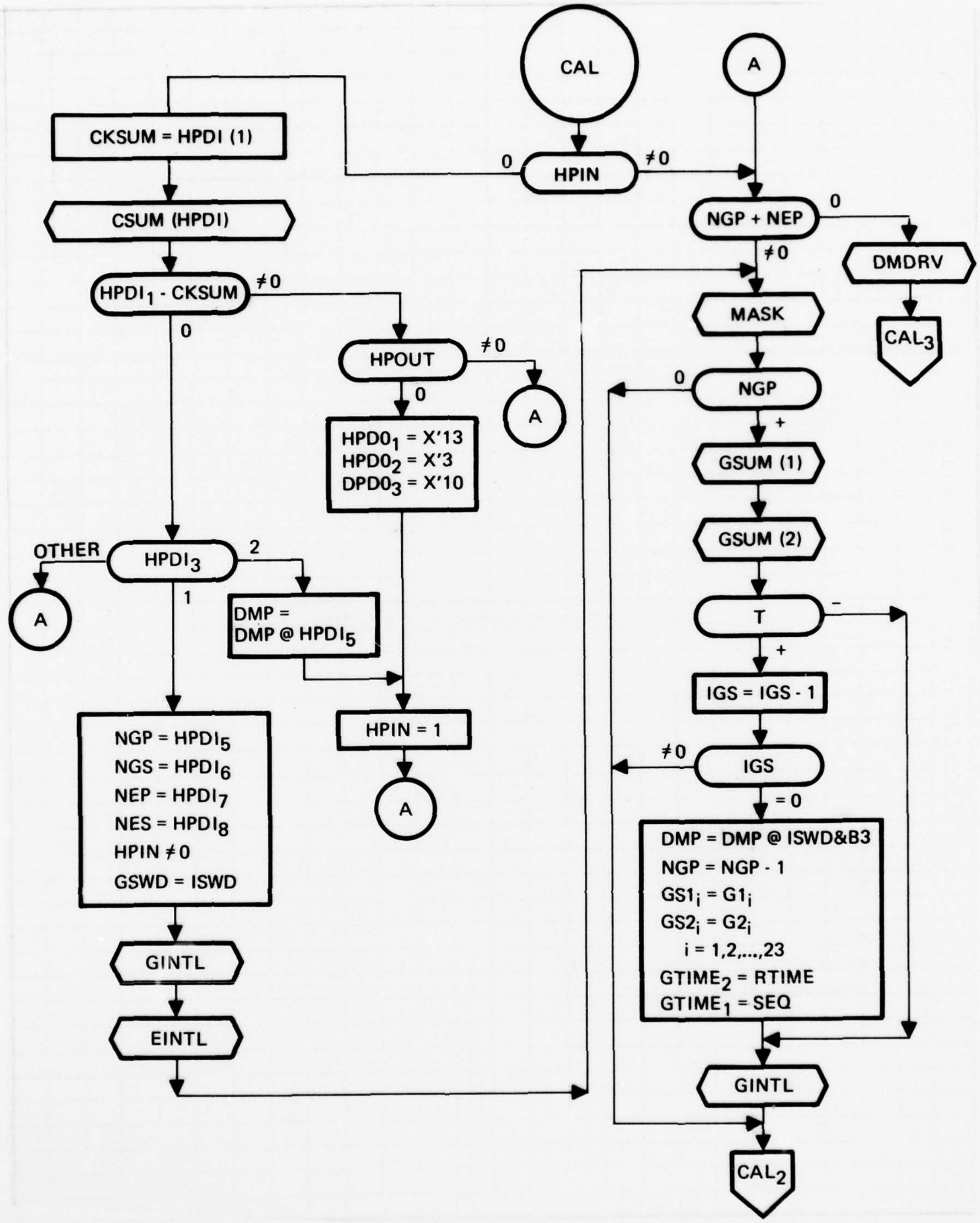

PROCESS

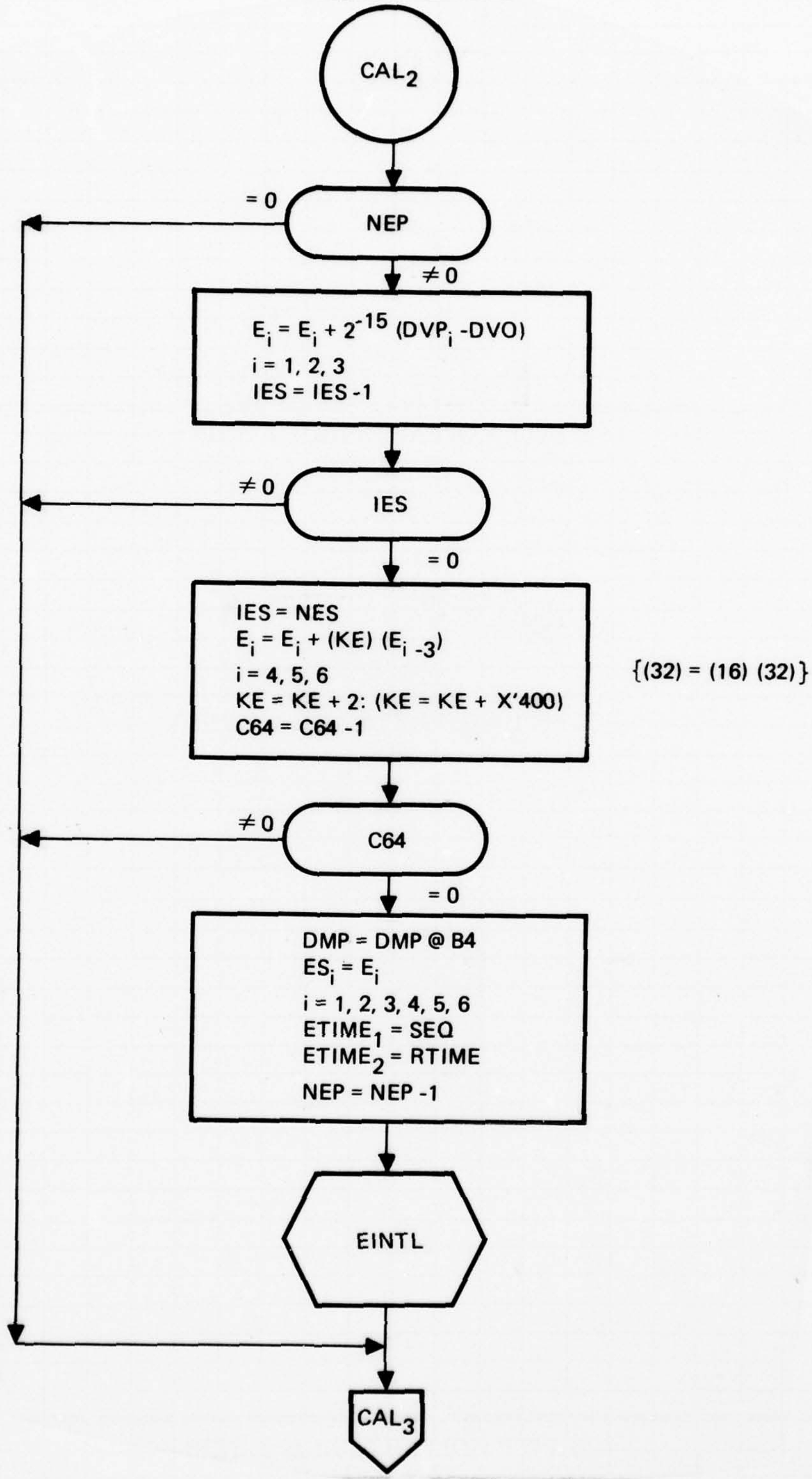

SUBROUTINE

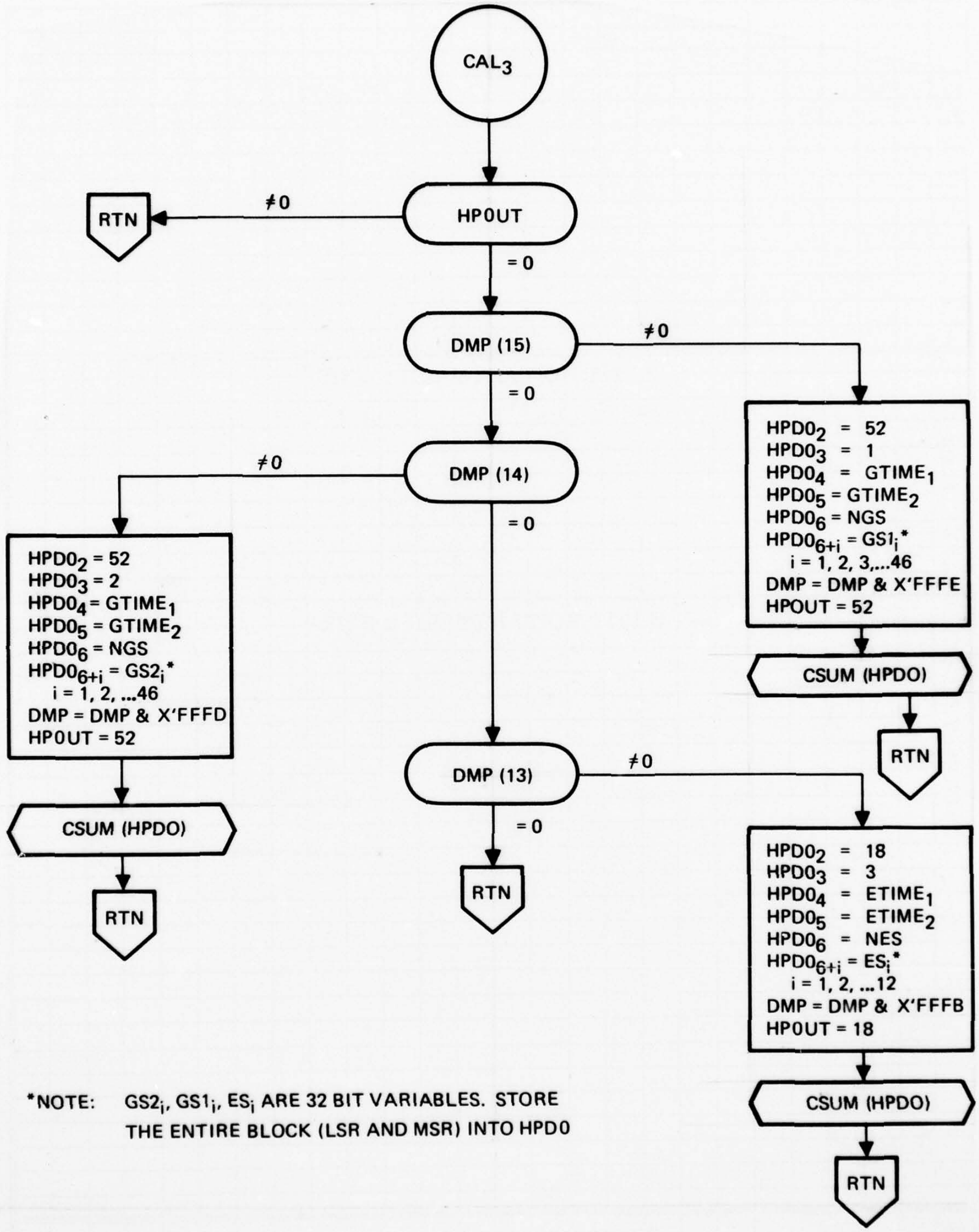

BRANCH POINT


OFF-PAGE CONNECTOR


OFF-PAGE BRANCH


CAL
A
CKSUM = HPDI (1)
0
HPIN
≠0
CSUM (HPDI)
NGP + NEP
0
≠0
DMDRV
HPDI1 - CKSUM
≠0
0
MASK
CAL3
HPOUT
≠0
0
A
0
NGP
+
HPD01 = X'13
HPD02 = X'3
DPD03 = X'10
GSUM (1)
GSUM (2)
OTHER
HPDI3
2
1
A
DMP =
DMP @ HPDI5
T
-
+
IGS = IGS - 1
NGP = HPDI5
NGS = HPDI6
NEP = HPDI7
NES = HPDI8
HPIN ≠0
GSWD = ISWD
HPIN = 1
A
≠0
IGS
= 0
DMP = DMP @ ISWD&B3
NGP = NGP - 1
GS1i = G1i
GS2i = G2i
i = 1,2,...,23
GTIME2 = RTIME
GTIME1 = SEQ
GINTL
EINTL
GINTL
CAL2


CAL2
= 0
NEP
≠ 0
Ei = Ei + 2-15 (DVPi -DVO)
i = 1, 2, 3
IES = IES -1
≠ 0
IES
= 0
IES = NES
Ei = Ei + (KE) (Ei -3)
i = 4, 5, 6
KE = KE + 2: (KE = KE + X'400)
C64 = C64 -1
{(32) = (16) (32)}
≠ 0
C64
= 0
DMP = DMP @ B4
ESi = Ei
i = 1, 2, 3, 4, 5, 6
ETIME1 = SEQ
ETIME2 = RTIME
NEP = NEP -1
EINTL
CAL3



*NOTE: $GS2_i$, $GS1_i$, ES_i ARE 32 BIT VARIABLES. STORE THE ENTIRE BLOCK (LSR AND MSR) INTO HPD0

GSUM$_{(i)}$

$TH = +SL + DMR0_1/DTC$: GYRO 1

$TH = -SL + DMR0_2/DTC$: GYRO 2

$CT = COS\ (TH)$

$ST = SIN\ (TH)$

$G_{i1} = G_{i1} + CT\ 2^{-10}$

$G_{i2} = G_{i2} + CT^2\ 2^{-10}$

$G_{i3} = G_{i3} + (CT)\ (ST)\ 2^{-10}$

$G_{i4} = G_{i4} + ST\ 2^{-10}$

$G_{i5} = G_{i5} + ST^2\ 2^{-10}$

$G_{i6} = G_{i6} + AL_{i1}\ CT\ 2^{-10}$

$G_{i7} = G_{i7} + AL_{i1}\ ST\ 2^{-10}$

$G_{i8} = G_{i8} + AL_{i1}\ 2^{-10}$

$G_{i9} = G_{i9} + AL_{i2}\ CT\ 2^{-10}$

$G_{i10} = G_{i10} + AL_{i2}\ ST\ 2^{-10}$

$G_{i11} = G_{i11} + AL_{i2}\ 2^{-10}$

$G_{i12} = G_{i12} + AL_{i3}\ CT\ 2^{-10}$

$G_{i13} = G_{i13} + AL_{i3}\ ST\ 2^{-10}$

$G_{i14} = G_{i14} + AL_{i3}\ 2^{-10}$

$G_{i15} = G_{i15} + BT_{i1}\ CT\ 2^{-10}$

$G_{i16} = G_{i16} + BT_{i1}\ ST\ 2^{-10}$

$G_{i17} = G_{i17} + BT_{i1}\ 2^{-10}$

$G_{i18} = G_{i18} + BT_{i2}\ CT\ 2^{-10}$

$G_{i19} = G_{i19} + BT_{i2}\ ST\ 2^{-10}$

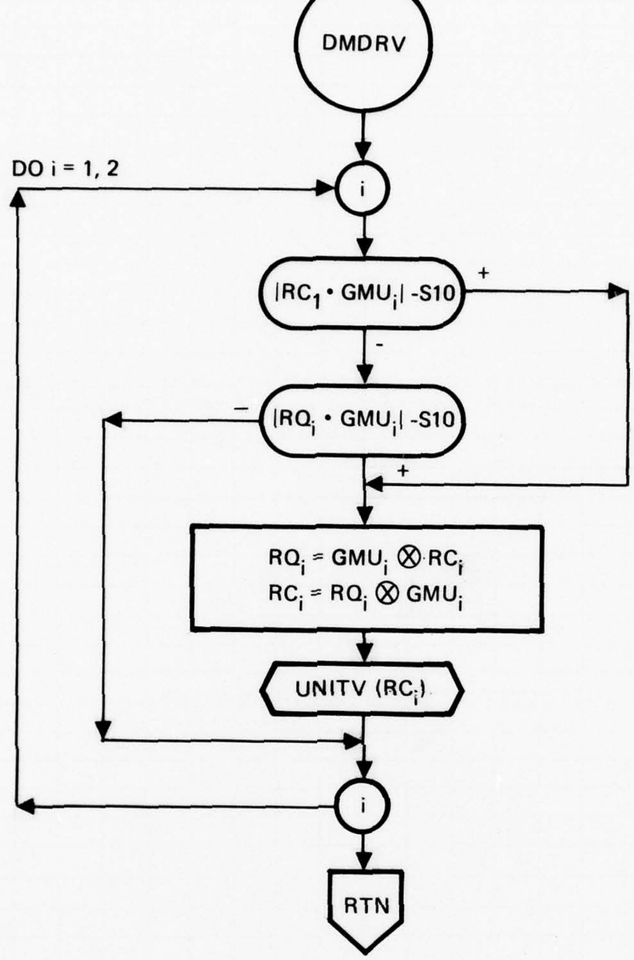
$G_{i20} = G_{i20} + BT_{i2}\ 2^{-10}$

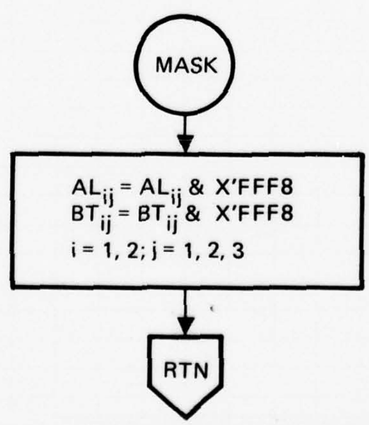
$G_{i21} = G_{i21} + BT_{i3}\ CT\ 2^{-10}$

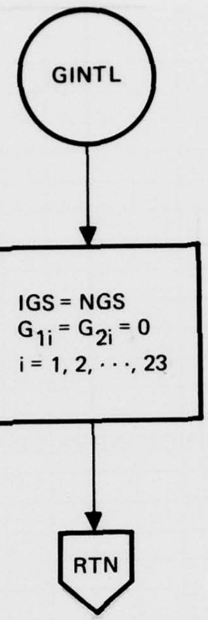
$G_{i22} = G_{i22} + BT_{i3}\ ST\ 2^{-10}$

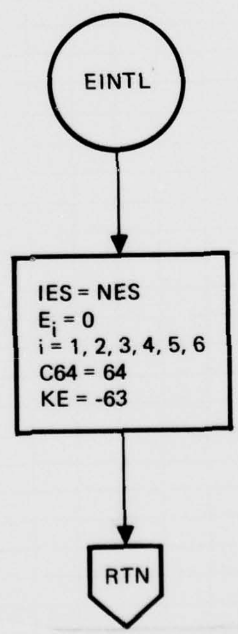
$G_{i23} = G_{i23} + BT_{i3}\ 2^{-10}$

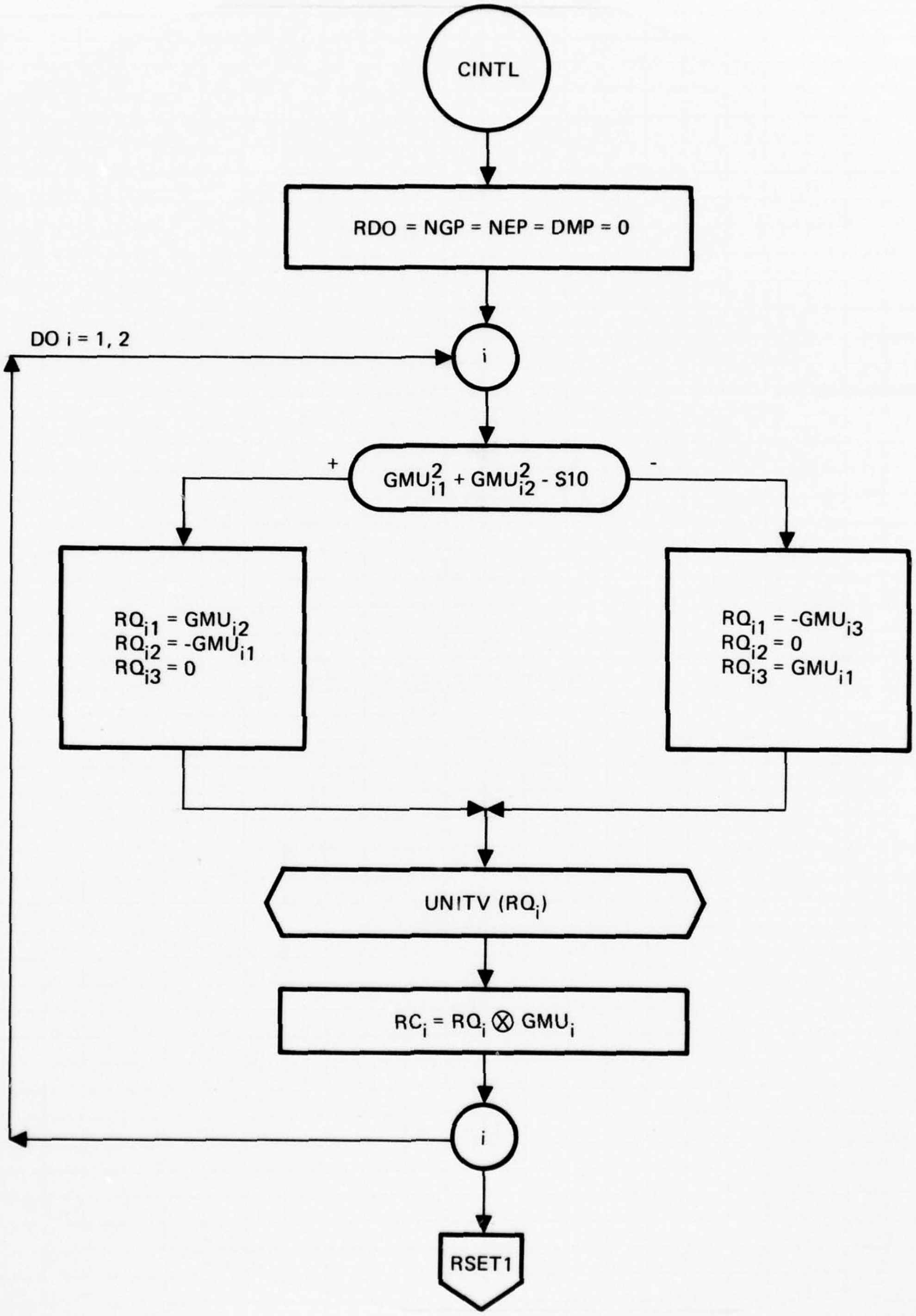
RTN

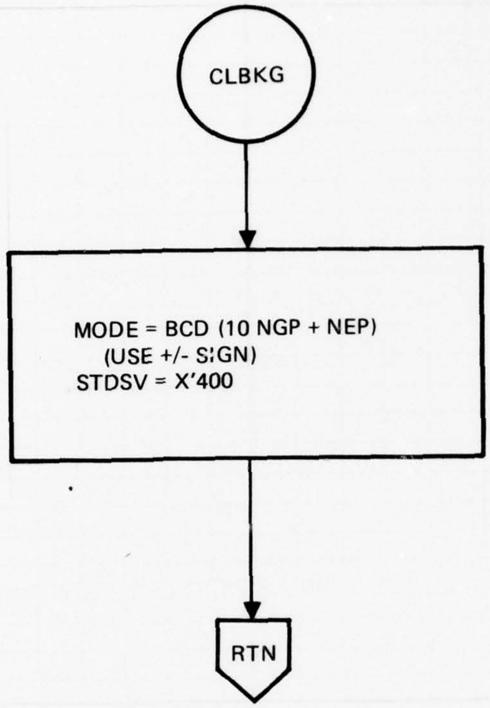

DMDRV
DO i = 1, 2
i
|RC1 • GMUi| -S10
+
-
|RQi • GMUi| -S10
–
+
RQi = GMUi ⊗ RCi
RCi = RQi ⊗ GMUi
UNITV (RCi)
i
RTN


MASK
ALij = ALij & X'FFF8
BTij = BTij & X'FFF8
i = 1, 2; j = 1, 2, 3
RTN


GINTL
IGS = NGS
$G_{1i} = G_{2i} = 0$
i = 1, 2, · · ·, 23
RTN


EINTL
IES = NES
$E_i = 0$
i = 1, 2, 3, 4, 5, 6
C64 = 64
KE = -63
RTN


CINTL
RDO = NGP = NEP = DMP = 0
DO i = 1, 2
i
$GMU_{i1}^2 + GMU_{i2}^2 - S10$
+
-
$RQ_{i1} = GMU_{i2}$
$RQ_{i2} = -GMU_{i1}$
$RQ_{i3} = 0$
$RQ_{i1} = -GMU_{i3}$
$RQ_{i2} = 0$
$RQ_{i3} = GMU_{i1}$
UNITV (RQ_i)
$RC_i = RQ_i \otimes GMU_i$
i
RSET1


CLBKG
MODE = BCD (10 NGP + NEP)
(USE +/- SIGN)
STDSV = X'400
RTN

AD-A048 001 ROCKWELL INTERNATIONAL ANAHEIM CALIF AUTONETICS GROUP F/G 17/7
MICRO NAVIGATOR (MICRON) PHASE 2B. VOLUME II - APPENDICES.(U)
AUG 77 J M MILLER, A P ANDREWS, T F BRASHER F33615-75-C-1301
UNCLASSIFIED C75-787/201-VOL-2 AFAL-TR-77-138-VOL-2 NL

3 OF 4
ADI
A048001

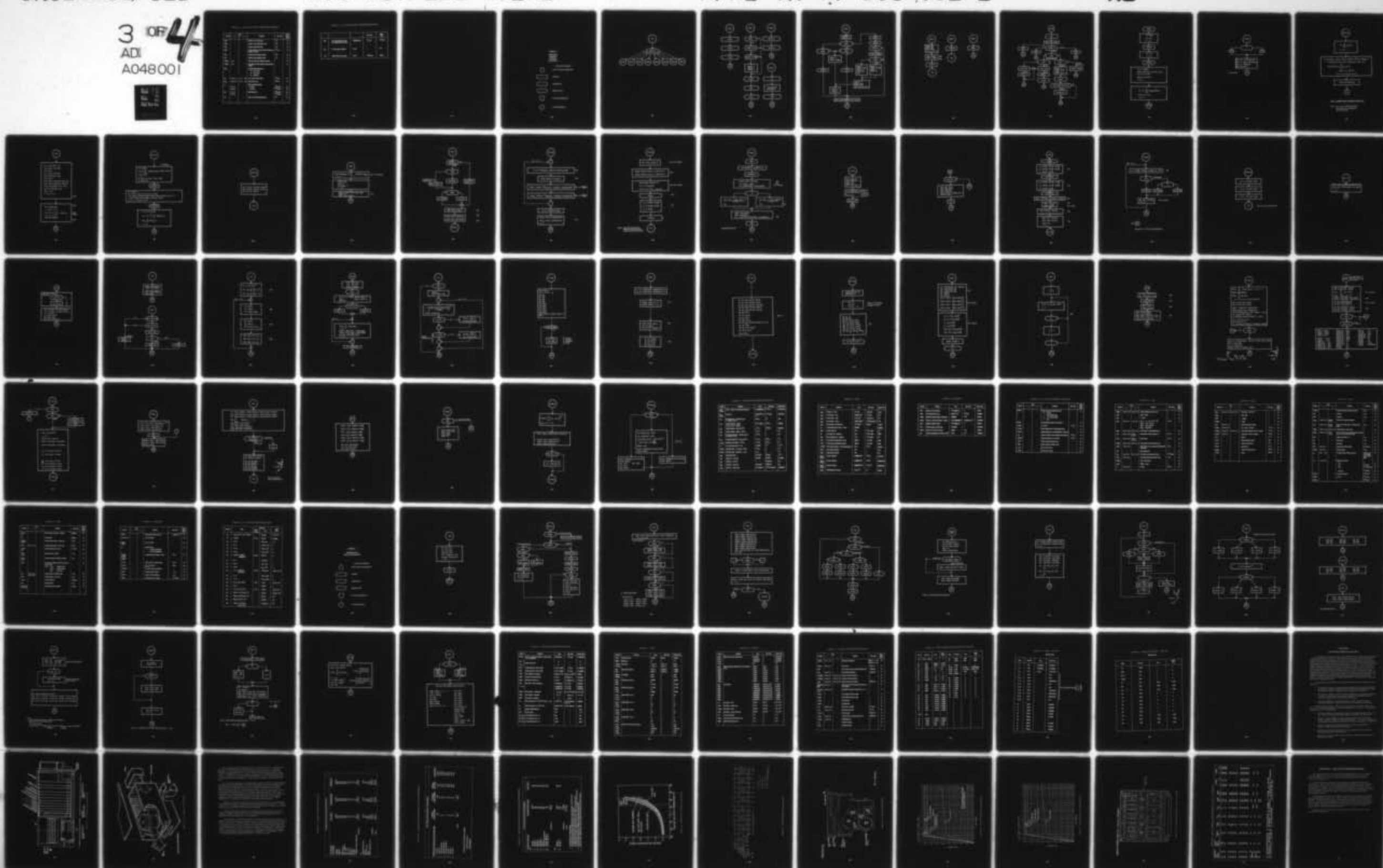


TABLE J-1. CAL DATA COLLECT PROGRAM VARIABLES

Symbol	Index		Description	Max Value	Word Length (Bits)
	i	j			
NGP	–	–	Number of Gyro Data Points	2^{15}	16
NGS	–	–	Number of Gyro Samples/Data Point	2^{15}	16
NEP	–	–	Number of EMA Data Points	2^{15}	16
NES	–	–	Length of EMA Data Point Collection (Number of Samples = 64 NES	2^{15} sec	16
IGS	–	–	Sample Counter Initialized to NGS	2^{15}	16
IES	–	–	Sample Counter Initialized to NES	2^{15}	16
GTIME	(1, 2)	–	Time Gyro Data Point Collection Complete	–	16
ETIME	(1, 2)	–	Time EMA Data Point Collection Complete (SEQ, RTIME)	–	16
DMP	–	–	HP Output Mode Word Bit Set: 15 – Gyro 1 Data 14 – Gyro 2 Data 13 – EMA Data		
G_{ij}	Gyro (1, 2)	(1, 2, . . . 23)	Gyro Fourier Analysis Results	2^{10} rad	32
GS_{ij}	Gyro (1, 2)	(1, 2, . . . 23)	Saved Values of G_{ij}	2^{10} rad	32
E_i		–	EMA Least Squares Results		
	(1, 2, 3)		(Σ pulse)	2^{24} pulses	32
	(4, 5, 6)		($\Sigma\Sigma$ pulse)	2^{30} pulses	32
ES_i	(1, 2, 3)	–	Saved Values of E_i	2^{24} pulses	32
	(4, 5, 6)			2^{30} pulses	32
KE	–	–	EMA Least Squares Weighting Factor	2^6	16

TABLE J-2. CAL DATA COLLECT PROGRAM CONSTANTS

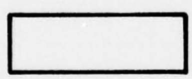
			Max Value	Scaled Value
DVO	Zero Acceleration Pulse Count (Use Integer Number of Pulses)	20000/64 pulse	2^9 pulse	2^{-9} (312)
S10	R Vector Update Threshold	sin 10°	1	0.17
DTC	Residual Demod Freq Scaling	64/sec	2604.16 Hz	0.0246

APPENDIX K

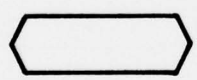
NAVIGATION PROGRAM DETAILED FLOW CHARTS

FLOW CHART SYMBOLS

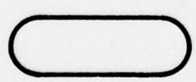
ENTRY POINT OR CONNECTOR



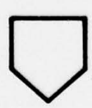
PROCESS



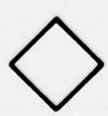
SUBROUTINE



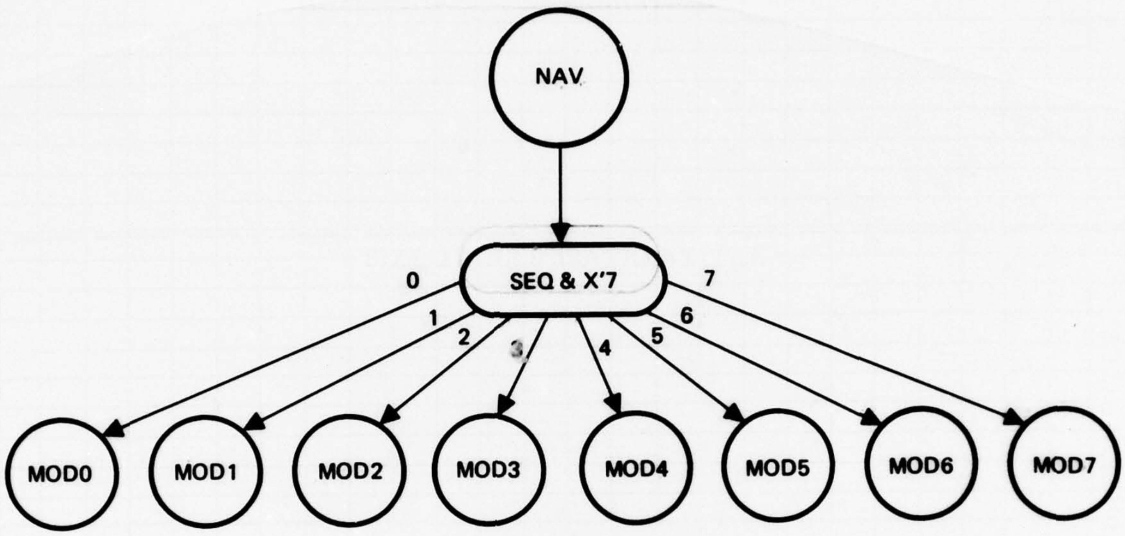
BRANCH POINT

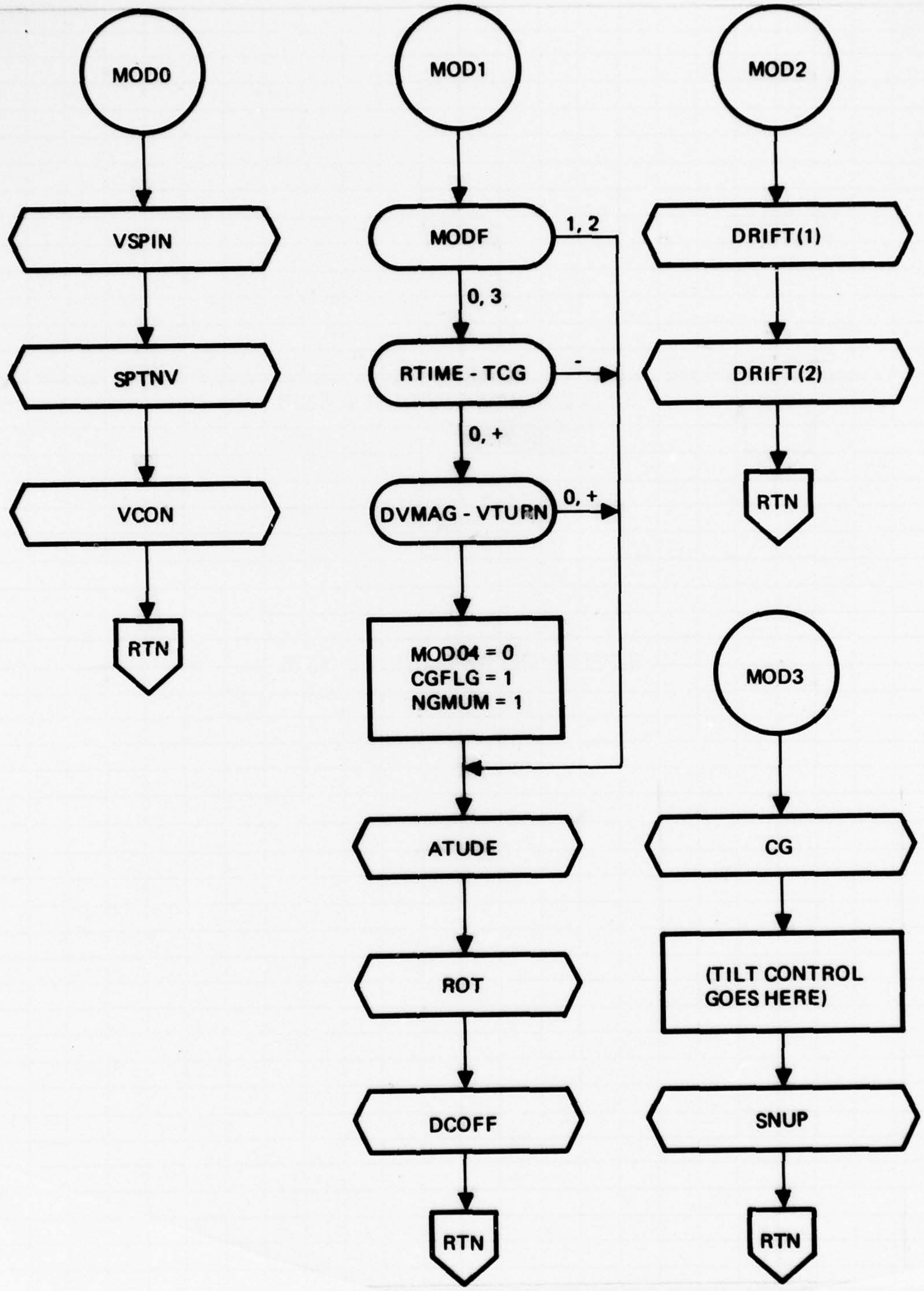


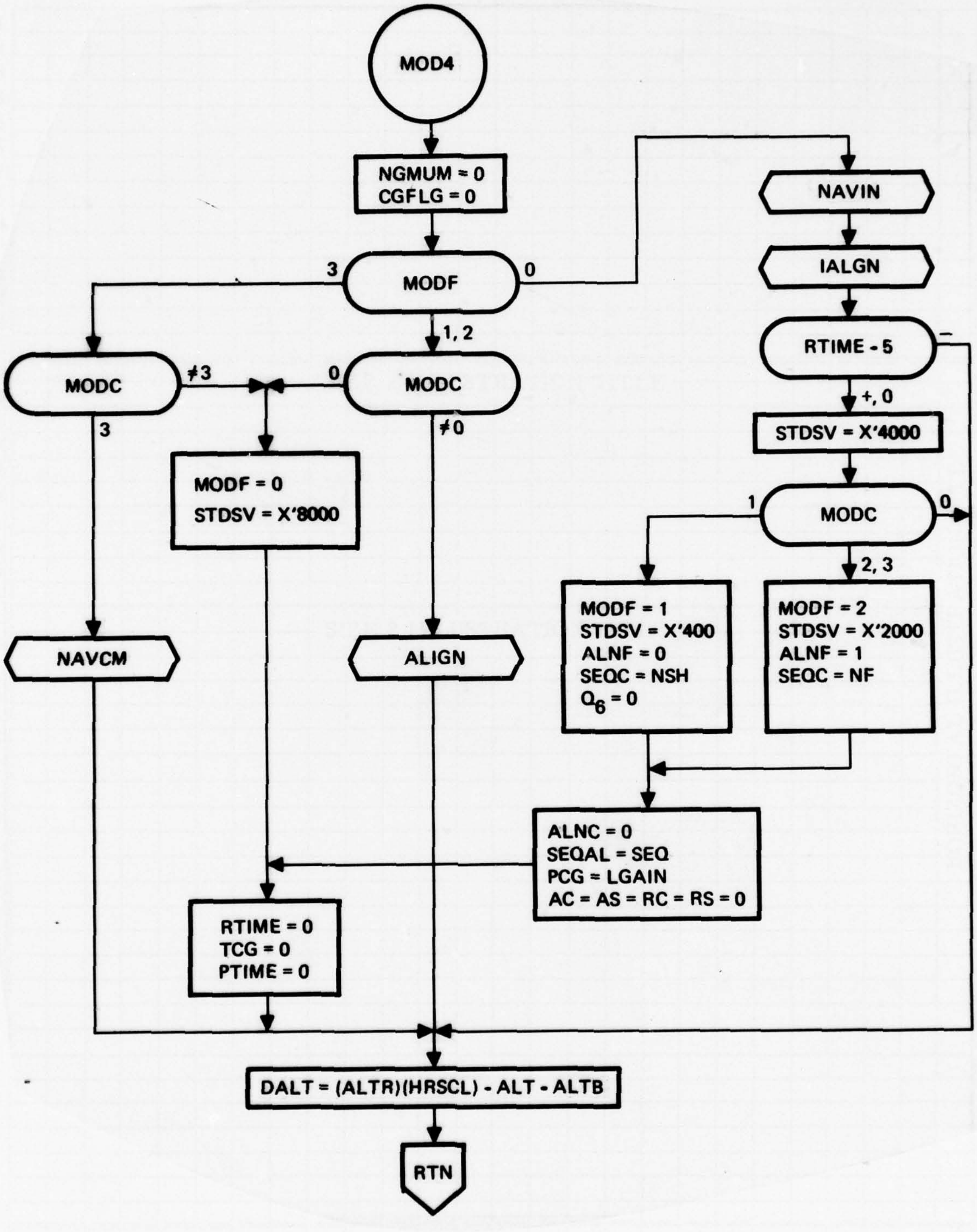
OFF-PAGE CONNECTOR

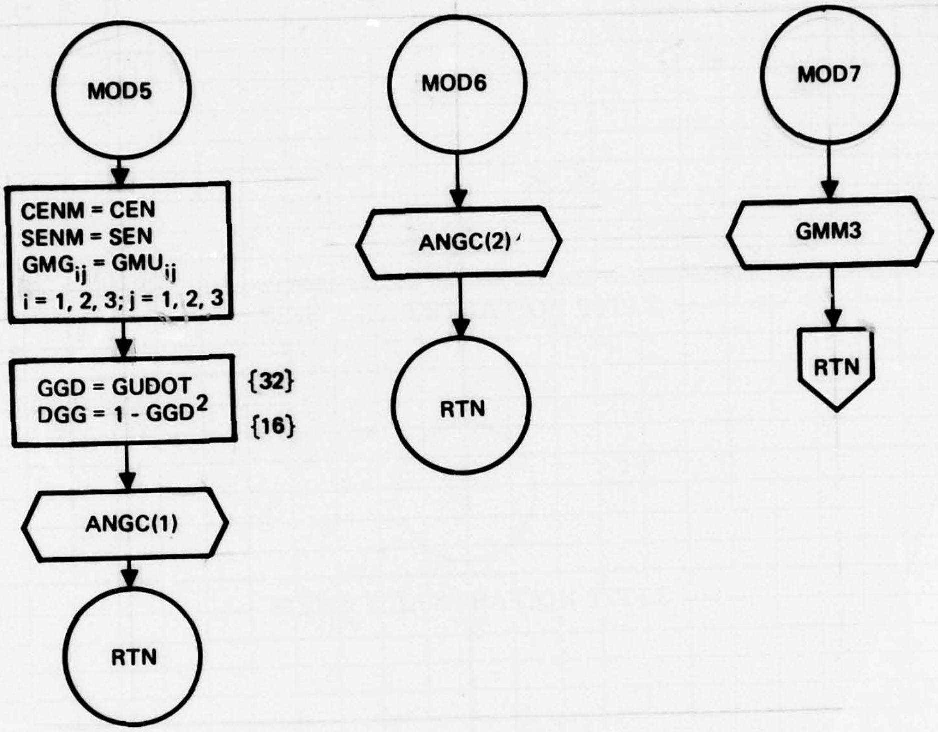


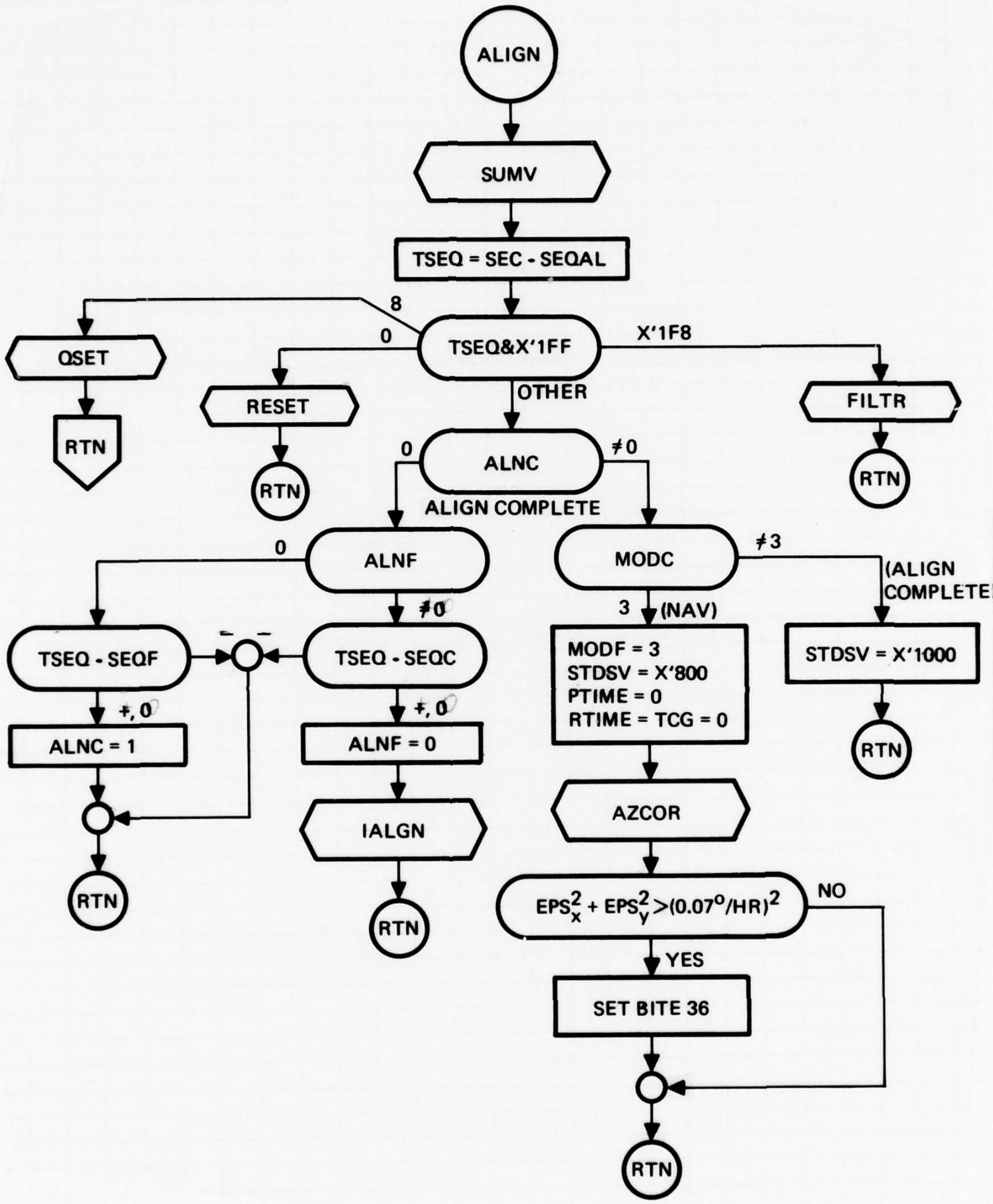
OFF-PAGE BRANCH

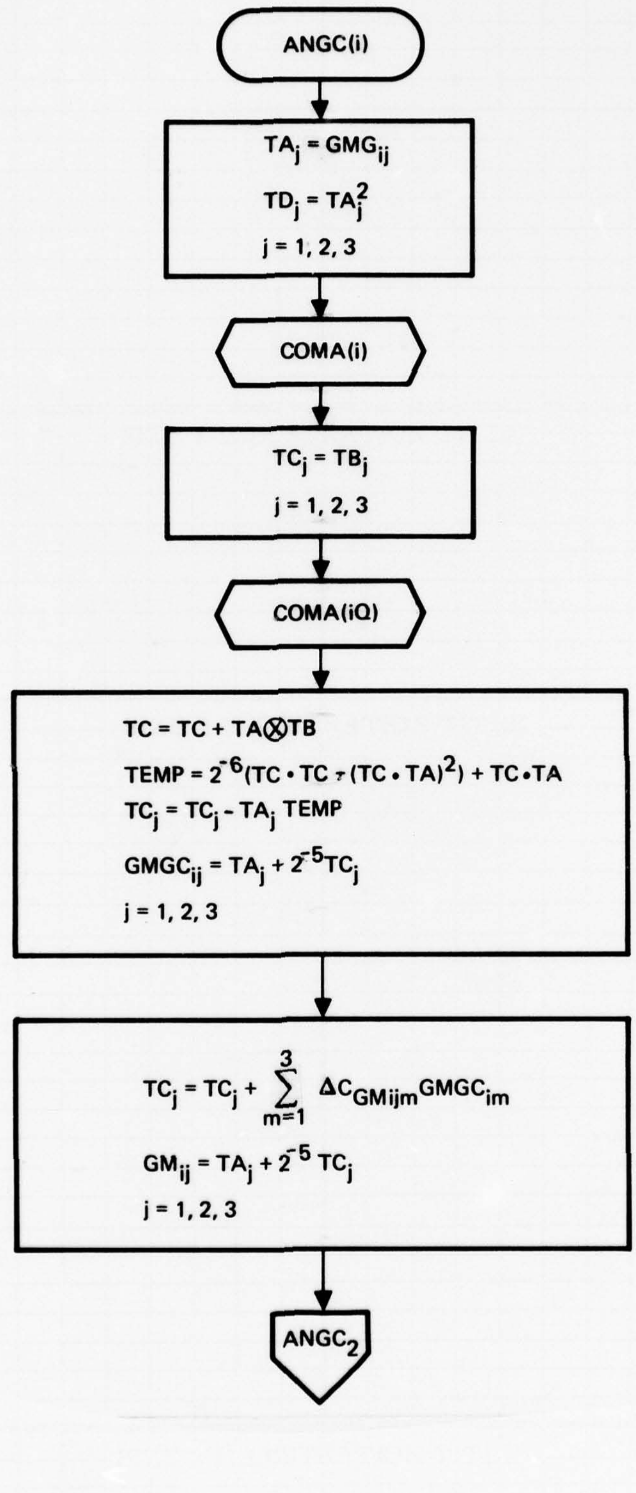

NAV
SEQ & X'7
0
1
2
3
4
5
6
7
MOD0
MOD1
MOD2
MOD3
MOD4
MOD5
MOD6
MOD7

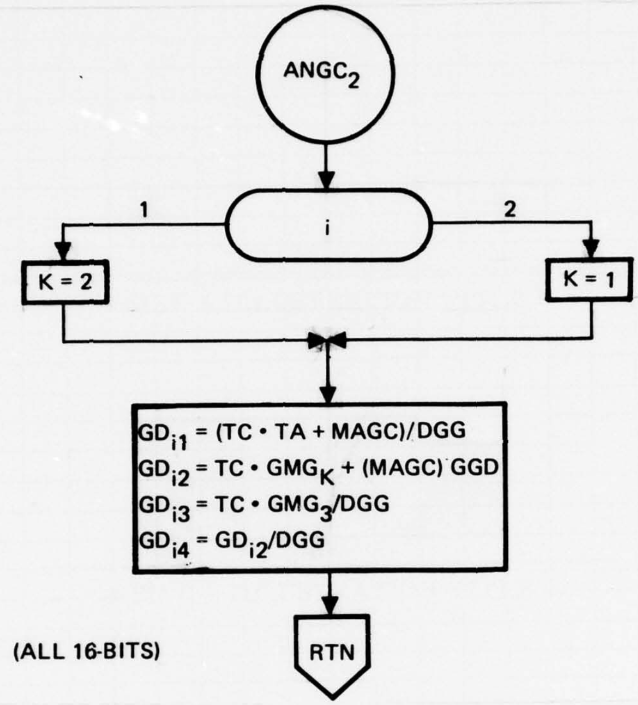

MOD0
VSPIN
SPTNV
VCON
RTN
MOD1
MODF
1, 2
0, 3
RTIME - TCG
-
0, +
DVMAG - VTURN
0, +
MOD04 = 0
CGFLG = 1
NGMUM = 1
ATUDE
ROT
DCOFF
RTN
MOD2
DRIFT(1)
DRIFT(2)
RTN
MOD3
CG
(TILT CONTROL
GOES HERE)
SNUP
RTN

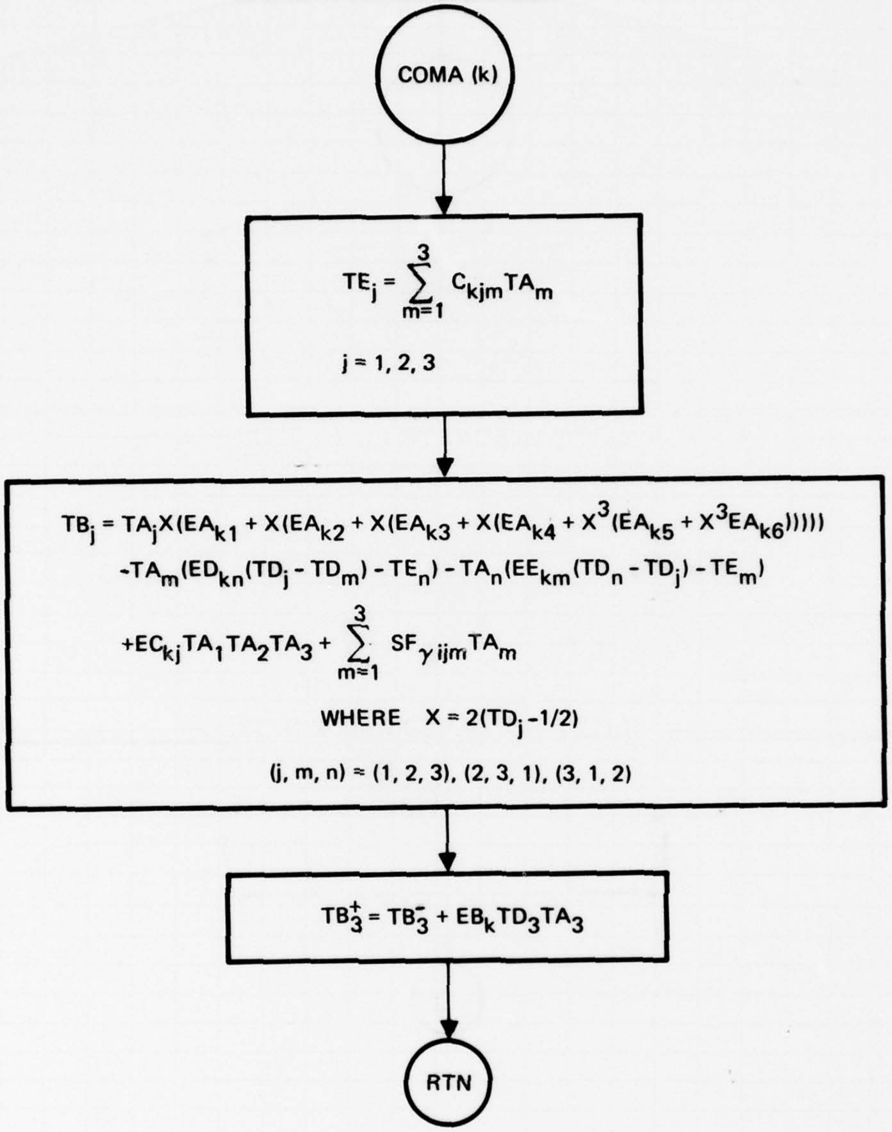

MOD4
NGMUM = 0
CGFLG = 0
MODF
3
0
1, 2
MODC
≠3
0
MODC
3
≠0
MODF = 0
STDSV = X'8000
NAVCM
ALIGN
NAVIN
IALGN
RTIME - 5
–
+, 0
STDSV = X'4000
1
MODC
0
2, 3
MODF = 1
STDSV = X'400
ALNF = 0
SEQC = NSH
Q_6 = 0
MODF = 2
STDSV = X'2000
ALNF = 1
SEQC = NF
ALNC = 0
SEQAL = SEQ
PCG = LGAIN
AC = AS = RC = RS = 0
RTIME = 0
TCG = 0
PTIME = 0
DALT = (ALTR)(HRSCL) - ALT - ALTB
RTN


MOD5
CENM = CEN
SENM = SEN
GMG$_{ij}$ = GMU$_{ij}$
i = 1, 2, 3; j = 1, 2, 3
GGD = GUDOT
DGG = 1 - GGD^2
{32}
{16}
ANGC(1)
RTN
MOD6
ANGC(2)
RTN
MOD7
GMM3
RTN


ALIGN
SUMV
TSEQ = SEC - SEQAL
8
0
TSEQ&X'1FF
X'1F8
QSET
RTN
RESET
RTN
OTHER
FILTR
RTN
0
ALNC
≠0
ALIGN COMPLETE
0
ALNF
MODC
≠3
(ALIGN COMPLETE)
≠0
3
(NAV)
TSEQ - SEQF
TSEQ - SEQC
MODF = 3
STDSV = X'800
PTIME = 0
RTIME = TCG = 0
STDSV = X'1000
+, 0
+, 0
ALNC = 1
ALNF = 0
RTN
IALGN
AZCOR
RTN
RTN
$EPS_x^2 + EPS_y^2 > (0.07^o/HR)^2$
NO
YES
SET BITE 36
RTN


ANGC(i)
$TA_j = GMG_{ij}$
$TD_j = TA_j^2$
$j = 1, 2, 3$
COMA(i)
$TC_j = TB_j$
$j = 1, 2, 3$
COMA(iQ)
$TC = TC + TA \otimes TB$
$TEMP = 2^{-6}(TC \cdot TC - (TC \cdot TA)^2) + TC \cdot TA$
$TC_j = TC_j - TA_j\ TEMP$
$GMGC_{ij} = TA_j + 2^{-5} TC_j$
$j = 1, 2, 3$
$TC_j = TC_j + \sum_{m=1}^{3} \Delta C_{GMijm} GMGC_{im}$
$GM_{ij} = TA_j + 2^{-5}\ TC_j$
$j = 1, 2, 3$
$ANGC_2$


ANGC$_2$
1
i
2
K = 2
K = 1
$GD_{i1} = (TC \cdot TA + MAGC)/DGG$
$GD_{i2} = TC \cdot GMG_K + (MAGC) \cdot GGD$
$GD_{i3} = TC \cdot GMG_3/DGG$
$GD_{i4} = GD_{i2}/DGG$
(ALL 16-BITS)
RTN



COMA – COMMON ANGLE COMPENSATION ROUTINE

NOTE: $SF_{\gamma iq}$ is $PH_{\gamma i}$ IN PARAMETER LIST (ALL 16 BIT) ALL PARAMETERS ARE IN LIST $PRMG_i$

GM3

$ET_{11} = -GD_{14}\,GGD + GD_{11}$

$ET_{12} = GD_{14} - GD_{11}\,GGD$

$ET_{13} = GD_{13}$

$ET_{21} = GD_{24} - GD_{21}\,GGD$

$ET_{22} = -DG_{24}\,GGD + GD_{21}$

$ET_{23} = GD_{23}$

$ET_{31} = -GD_{13} + GD_{23}\,(GGD + GD_{12}\,2^{-5})$

$ET_{32} = -GD_{23} + GD_{13}\,(GGD + GD_{22}\,2^{-5})$

$ET_{33} = -GD_{14}\,GD_{22}2^{-5} + ET_{11} + ET_{22}$

$ET^{+}_{ij} = ET^{-}_{ij} + \frac{1}{16}\,(ETO^{-}_{ij} - ET^{-}_{ij})$

$ETO^{+}_{ij} = ET^{-}_{ij}$

$i = 1, 2, 3;\ j = 1, 2, 3$

16-BIT

16-BIT

$TA_{ij} = (KDSN) \cdot CSN_{ij}$

$i = 1, 2, 3,\ j = 1, 2, 3$

$CE_{ij} = TA_{ij} + 2^{-5} \sum_{K=1}^{3} TA_{iK}\,ET_{Kj}$ 16-BIT ROUND

$i = 1, 2, 3;\ j = 1, 2, 3$

$GM_3 = GM_1 \otimes GM_2$

32-BIT

RTN

DRIFT(i)

(K73 MODEL)

$TA_j = GMGC_{ij}$

$TG_j = (2^{-5} \sum_{m=1}^{3} DCGM_{imj} DVM_m + DVM_j)\ KVA2^{+2}$

$TAG_j = TA_j\ TG_j$

$j = 1, 2, 3$

$PT = P24_i - P11_i\ (TAG_1 + TAG_2 + TAG_3)$

$TC = PGUS \times TA$

DRI (PA_i)

$X = 2\ (TA_i^2 - 1/2)$

$TC_j = TC_j + P_{ji} + TB_j - P32_i\ (TA_n\ TG_m + TA_m\ TG_n)$

$+ TA_j\ X\ (PD6_{ji} + X\ (PD5_{ji} + X\ (PD4_{ji} + X\ (PD3_{ji} + X\ (PD2_{ji} + X(PD1_{ji} + X\ P31_i\ ))))))$

$- TG_j\ (PT + X\ (P33_i + X\ (P34_i + XP35_i)) - P4_i\ (TAG_m + TAG_n))$

$(j, m, n) = (1, 2, 3), (2,3,1), (3,1,2)$

DRI (PAQ_i)

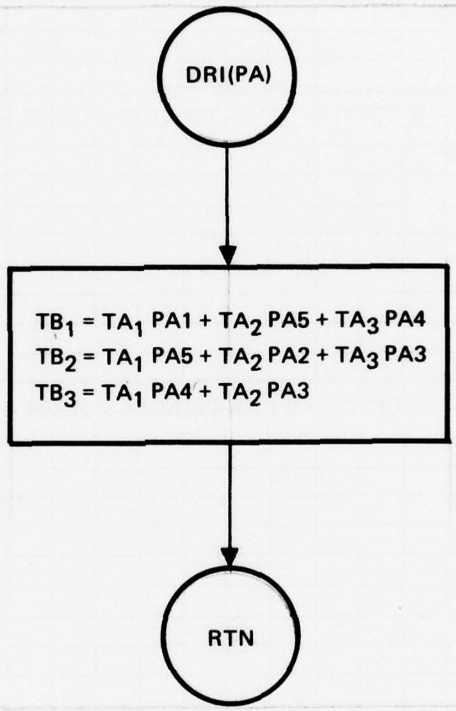
$TC = TC + TA \otimes TB$

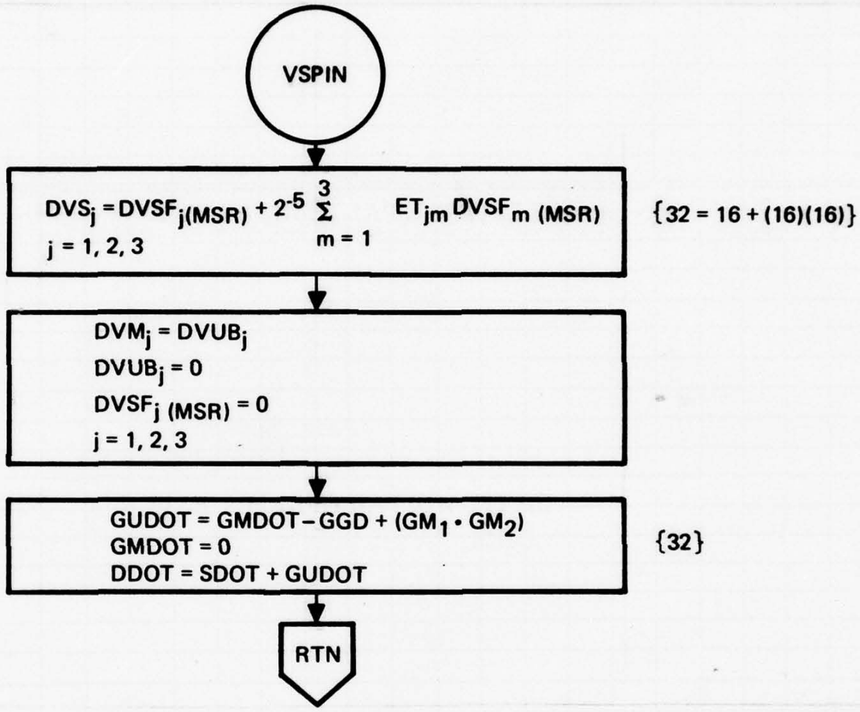
$TE_j = -TC_j - 2^{-5} \sum_{m=1}^{3} DCGM_{ijm}\ TC_m$

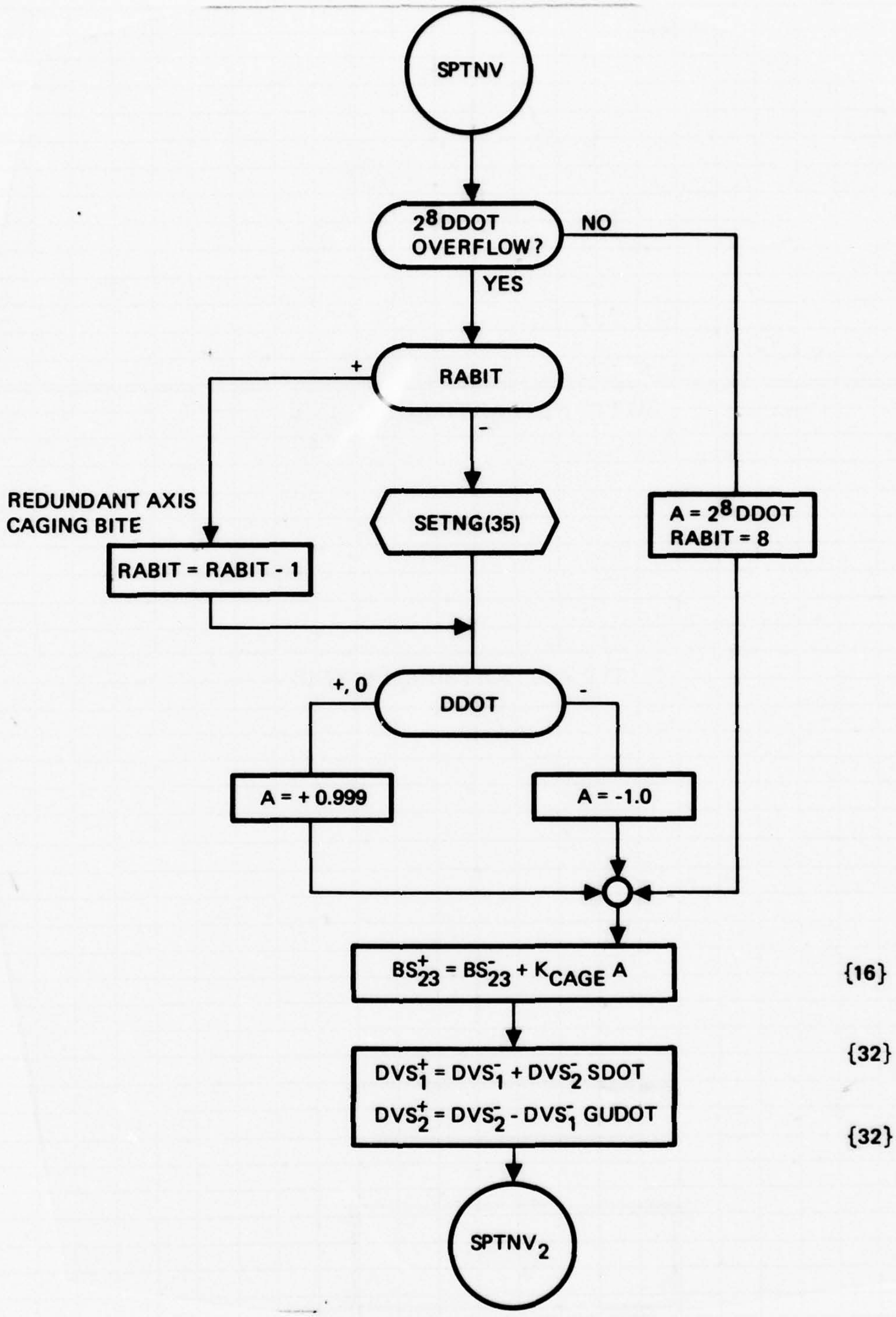
$BS_{ij} = \sum_{m=1}^{3} GM_{jm}\ TE_m$

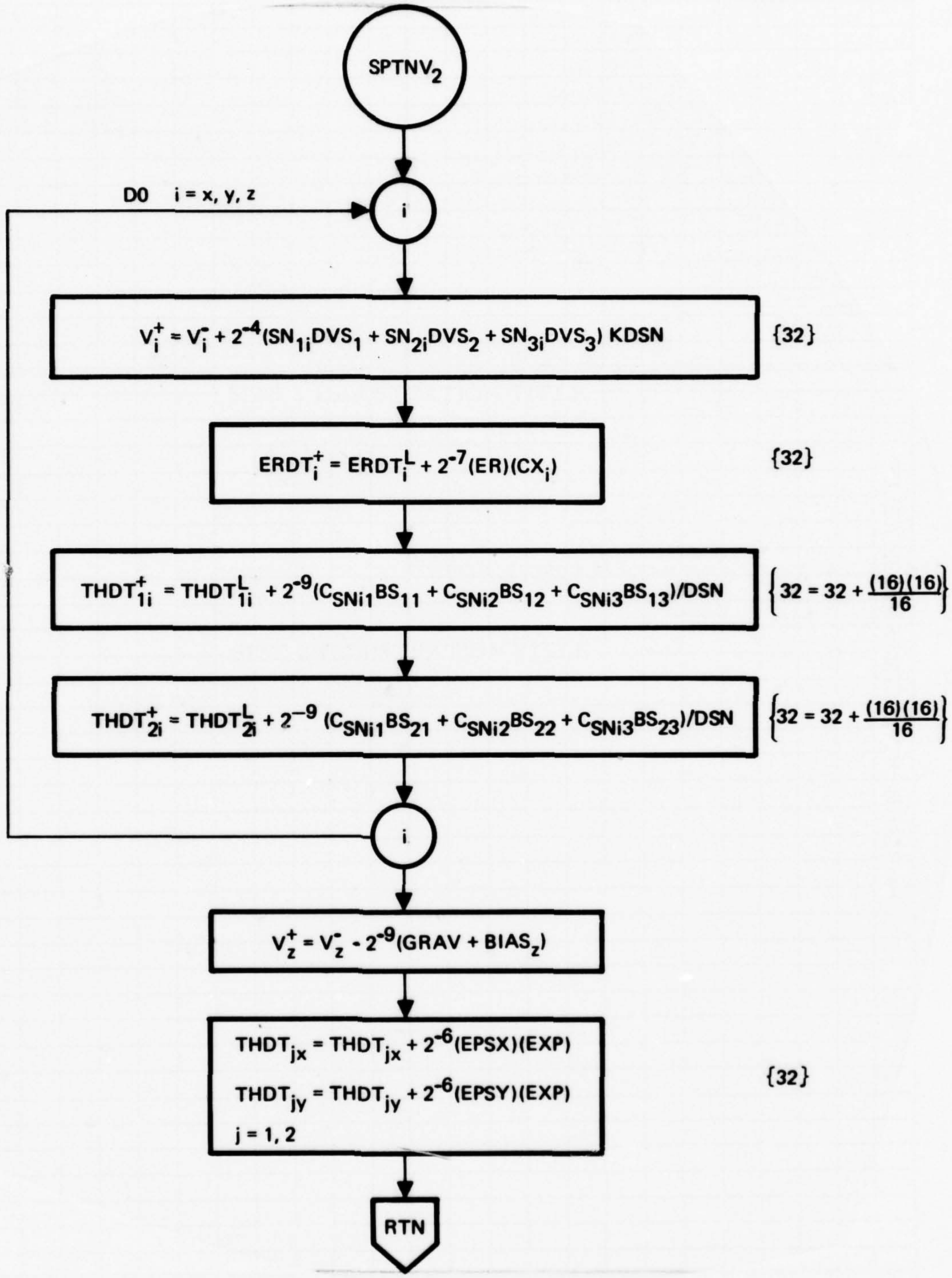
$j = 1, 2, 3$

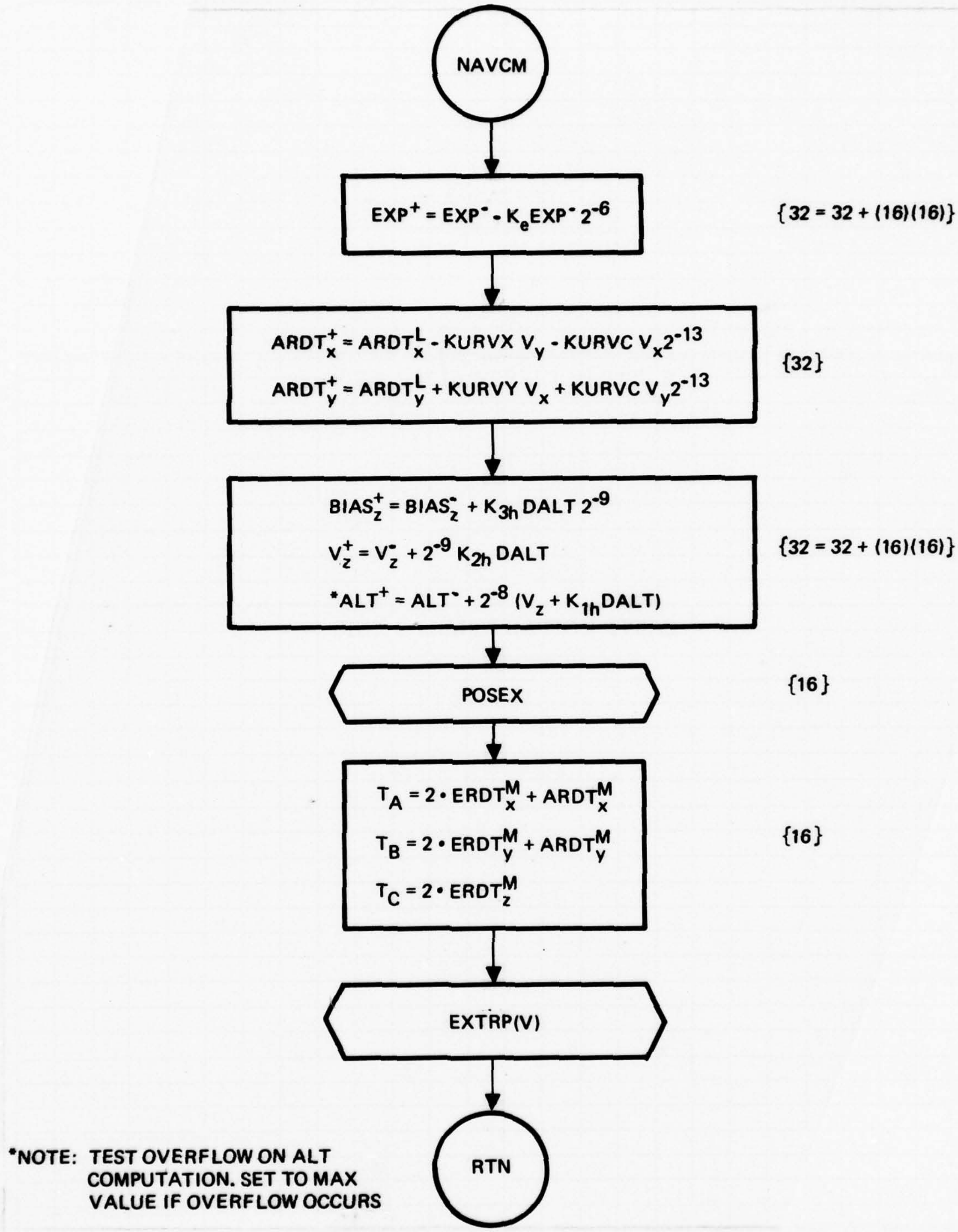
RTN

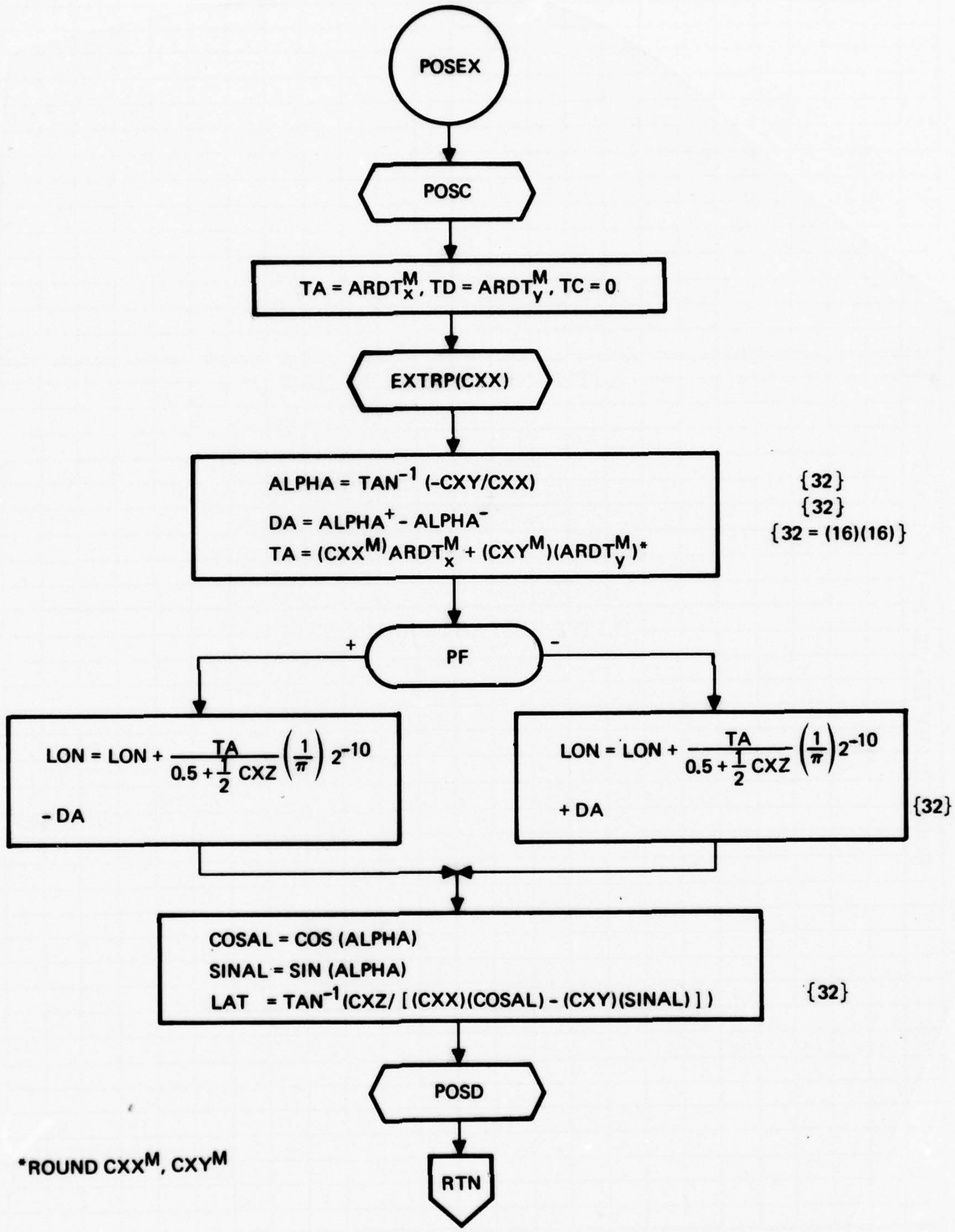

DRI(PA)
$TB_1 = TA_1\ PA1 + TA_2\ PA5 + TA_3\ PA4$
$TB_2 = TA_1\ PA5 + TA_2\ PA2 + TA_3\ PA3$
$TB_3 = TA_1\ PA4 + TA_2\ PA3$
RTN


VSPIN
$DVS_j = DVSF_{j(MSR)} + 2^{-5} \sum_{m=1}^{3} ET_{jm} DVSF_{m\ (MSR)}$
$j = 1, 2, 3$
$\{32 = 16 + (16)(16)\}$
$DVM_j = DVUB_j$
$DVUB_j = 0$
$DVSF_{j\ (MSR)} = 0$
$j = 1, 2, 3$
$GUDOT = GMDOT - GGD + (GM_1 \cdot GM_2)$
$GMDOT = 0$
$DDOT = SDOT + GUDOT$
$\{32\}$
RTN

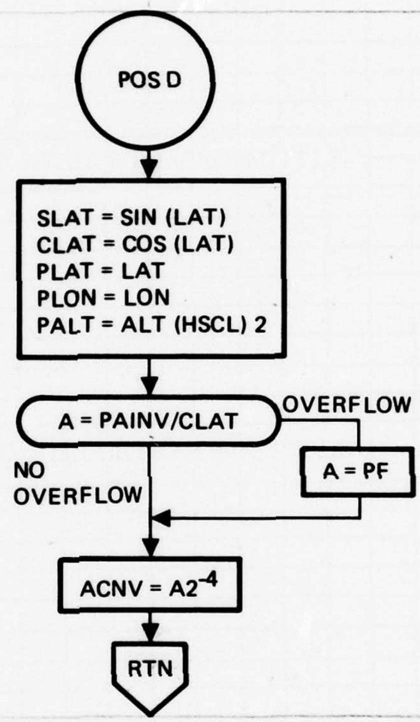

SPTNV
2^8DDOT OVERFLOW?
NO
YES
RABIT
+
-
REDUNDANT AXIS CAGING BITE
RABIT = RABIT - 1
SETNG(35)
A = 2^8DDOT
RABIT = 8
DDOT
+, 0
-
A = + 0.999
A = -1.0
$BS^+_{23} = BS^-_{23} + K_{CAGE}\ A$
{16}
$DVS^+_1 = DVS^-_1 + DVS^-_2$ SDOT
{32}
$DVS^+_2 = DVS^-_2 - DVS^-_1$ GUDOT
{32}
$SPTNV_2$

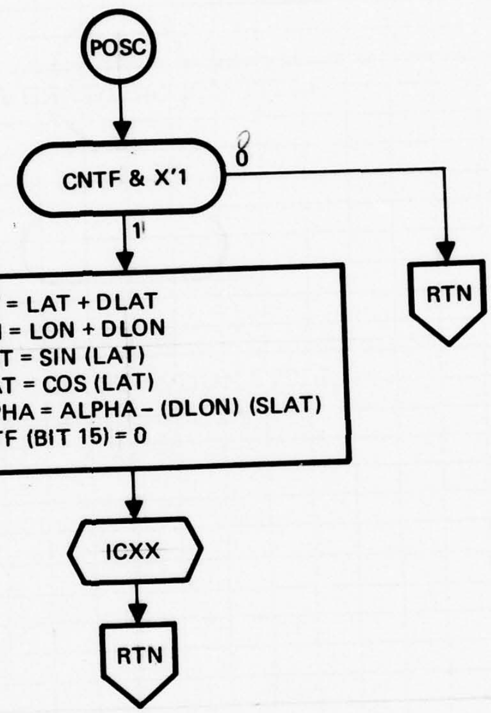

SPTNV$_2$
DO i = x, y, z
i
$V_i^+ = V_i^- + 2^{-4}(SN_{1i}DVS_1 + SN_{2i}DVS_2 + SN_{3i}DVS_3)$ KDSN
{32}
$ERDT_i^+ = ERDT_i^L + 2^{-7}(ER)(CX_i)$
{32}
$THDT_{1i}^+ = THDT_{1i}^L + 2^{-9}(C_{SNi1}BS_{11} + C_{SNi2}BS_{12} + C_{SNi3}BS_{13})/DSN$
$\left\{32 = 32 + \frac{(16)(16)}{16}\right\}$
$THDT_{2i}^+ = THDT_{2i}^L + 2^{-9}(C_{SNi1}BS_{21} + C_{SNi2}BS_{22} + C_{SNi3}BS_{23})/DSN$
$\left\{32 = 32 + \frac{(16)(16)}{16}\right\}$
i
$V_z^+ = V_z^- - 2^{-9}(GRAV + BIAS_z)$
$THDT_{jx} = THDT_{jx} + 2^{-6}(EPSX)(EXP)$
$THDT_{jy} = THDT_{jy} + 2^{-6}(EPSY)(EXP)$
j = 1, 2
{32}
RTN

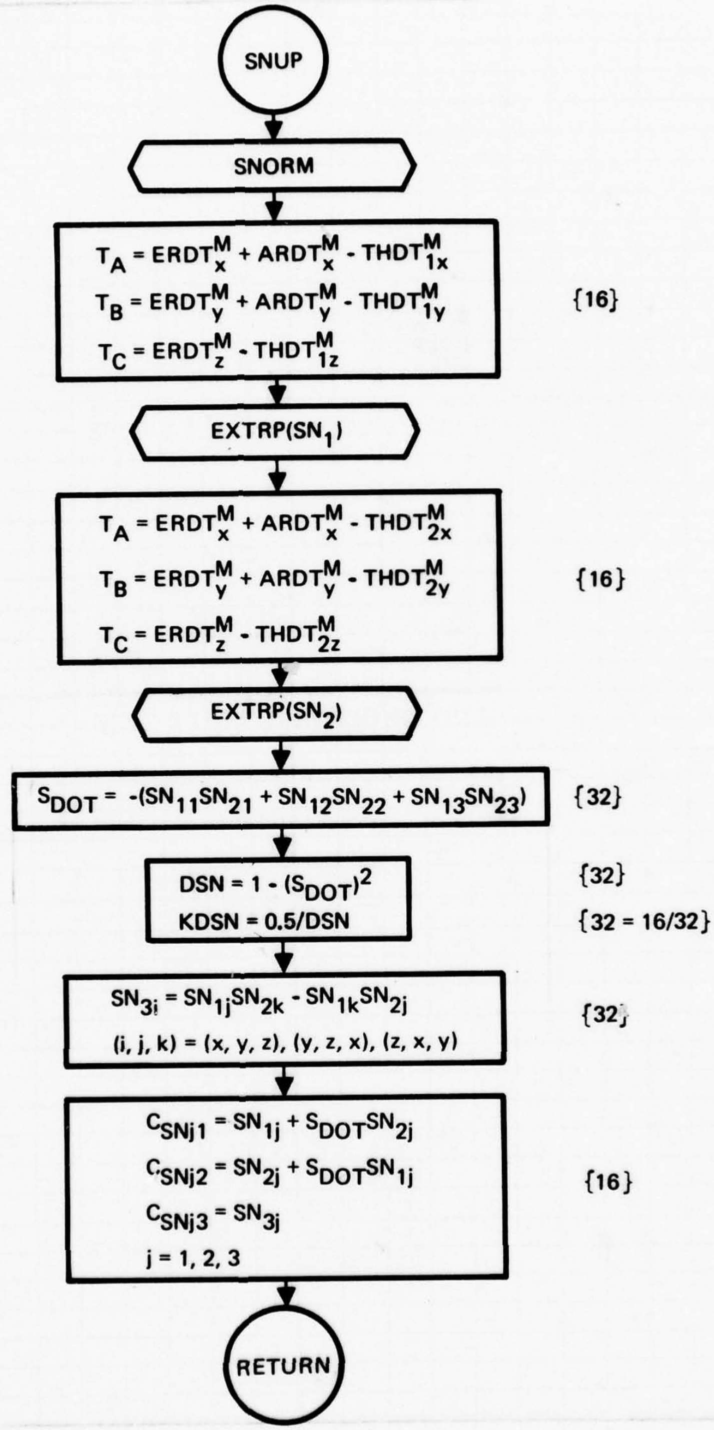

NAVCM
$EXP^{+} = EXP^{-} - K_e EXP^{-} 2^{-6}$
{32 = 32 + (16)(16)}
$ARDT_x^{+} = ARDT_x^{L} - KURVX\ V_y - KURVC\ V_x 2^{-13}$
$ARDT_y^{+} = ARDT_y^{L} + KURVY\ V_x + KURVC\ V_y 2^{-13}$
{32}
$BIAS_z^{+} = BIAS_z^{-} + K_{3h}\ DALT\ 2^{-9}$
$V_z^{+} = V_z^{-} + 2^{-9} K_{2h}\ DALT$
$^{*}ALT^{+} = ALT^{-} + 2^{-8} (V_z + K_{1h} DALT)$
{32 = 32 + (16)(16)}
POSEX
{16}
$T_A = 2 \cdot ERDT_x^M + ARDT_x^M$
$T_B = 2 \cdot ERDT_y^M + ARDT_y^M$
$T_C = 2 \cdot ERDT_z^M$
{16}
EXTRP(V)
RTN
*NOTE: TEST OVERFLOW ON ALT COMPUTATION. SET TO MAX VALUE IF OVERFLOW OCCURS

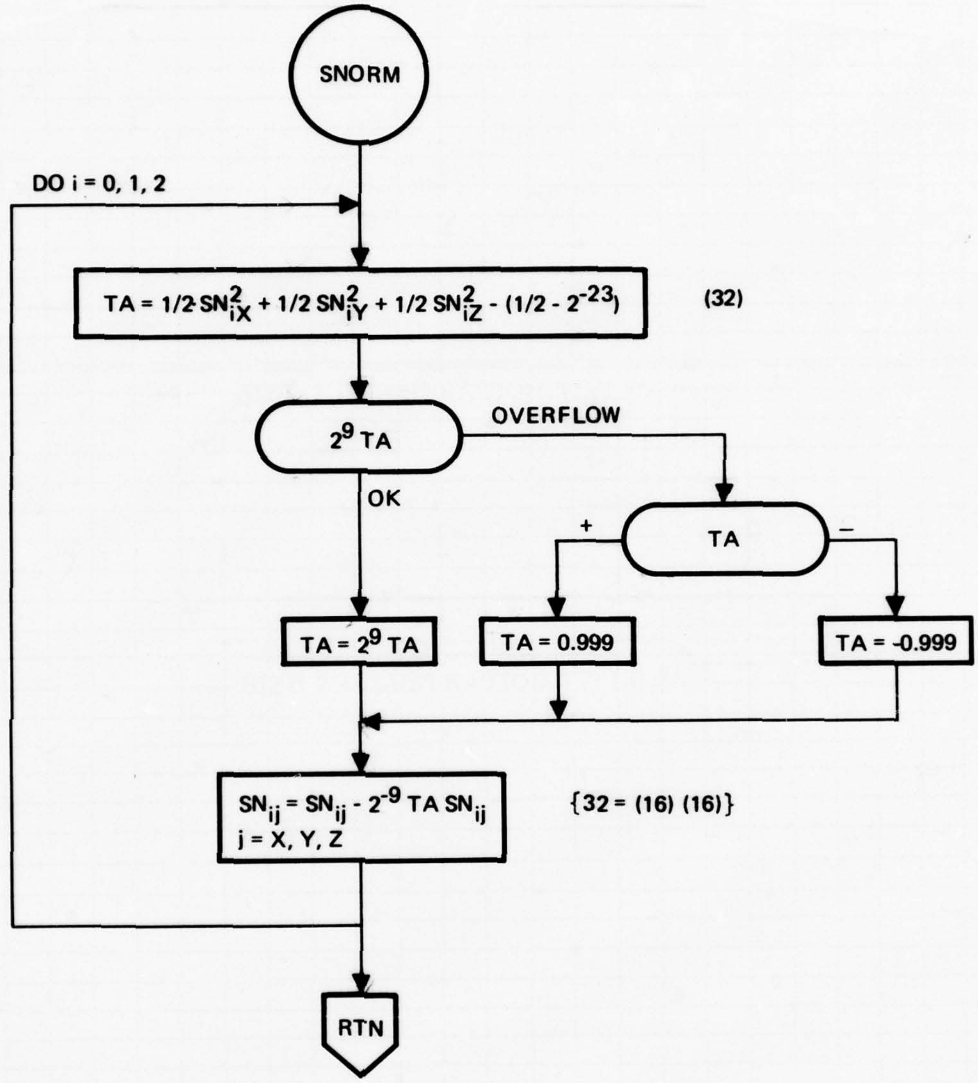


*ROUND CXX^M, CXY^M


POS D
SLAT = SIN (LAT)
CLAT = COS (LAT)
PLAT = LAT
PLON = LON
PALT = ALT (HSCL) 2
A = PAINV/CLAT
OVERFLOW
A = PF
NO OVERFLOW
ACNV = A2^-4
RTN

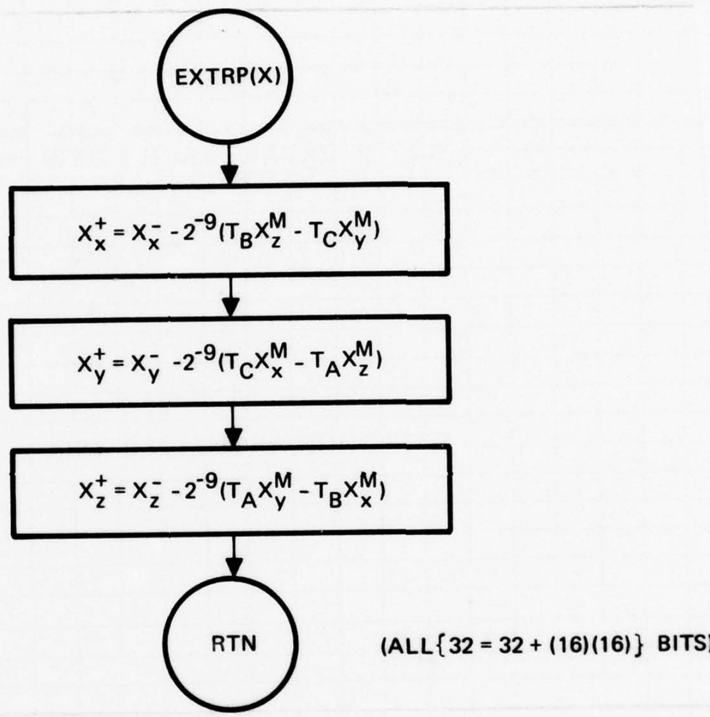

POSC
CNTF & X'1
0
1
RTN
LAT = LAT + DLAT
LON = LON + DLON
SLAT = SIN (LAT)
CLAT = COS (LAT)
ALPHA = ALPHA – (DLON) (SLAT)
CNTF (BIT 15) = 0
ICXX
RTN


SNUP
SNORM
$T_A = ERDT_x^M + ARDT_x^M - THDT_{1x}^M$
$T_B = ERDT_y^M + ARDT_y^M - THDT_{1y}^M$
$T_C = ERDT_z^M - THDT_{1z}^M$
{16}
EXTRP(SN_1)
$T_A = ERDT_x^M + ARDT_x^M - THDT_{2x}^M$
$T_B = ERDT_y^M + ARDT_y^M - THDT_{2y}^M$
$T_C = ERDT_z^M - THDT_{2z}^M$
{16}
EXTRP(SN_2)
$S_{DOT} = -(SN_{11}SN_{21} + SN_{12}SN_{22} + SN_{13}SN_{23})$
{32}
$DSN = 1 - (S_{DOT})^2$
{32}
$KDSN = 0.5/DSN$
{32 = 16/32}
$SN_{3i} = SN_{1j}SN_{2k} - SN_{1k}SN_{2j}$
$(i, j, k) = (x, y, z), (y, z, x), (z, x, y)$
{32}
$C_{SNj1} = SN_{1j} + S_{DOT}SN_{2j}$
$C_{SNj2} = SN_{2j} + S_{DOT}SN_{1j}$
$C_{SNj3} = SN_{3j}$
$j = 1, 2, 3$
{16}
RETURN

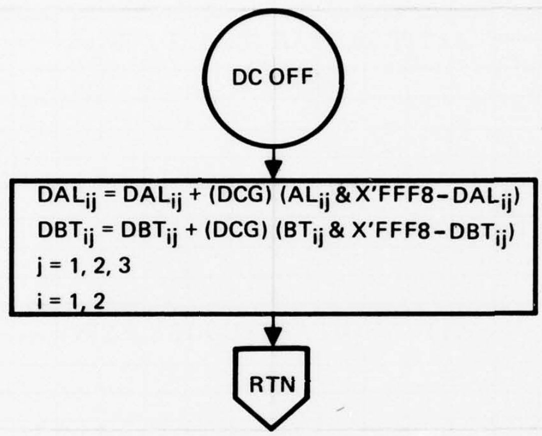


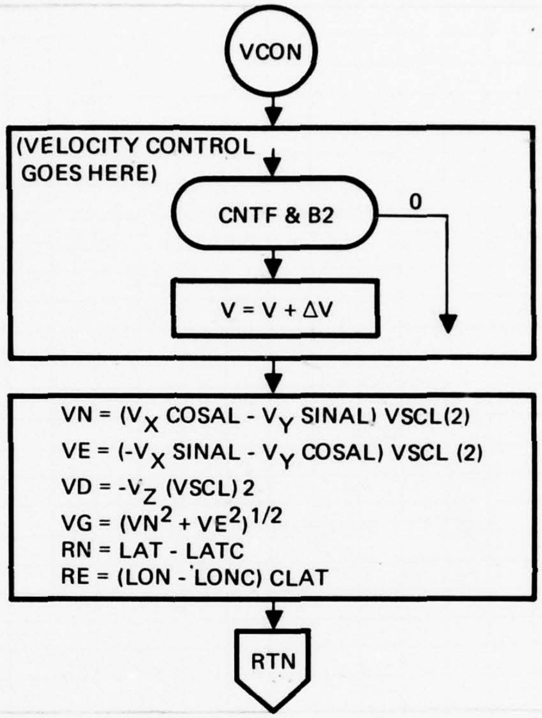
$$SN_0 \equiv \begin{bmatrix} CXX \\ CXY \\ CXZ \end{bmatrix}$$

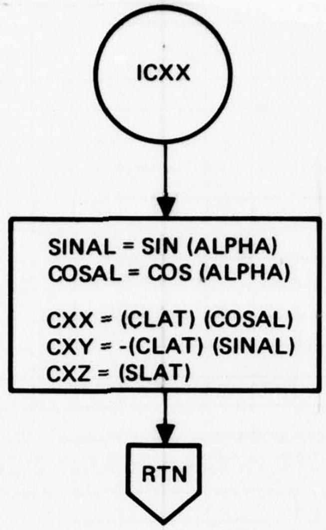
SCALES TO (1 - 2^{-22}) VECTOR MAGNITUDE

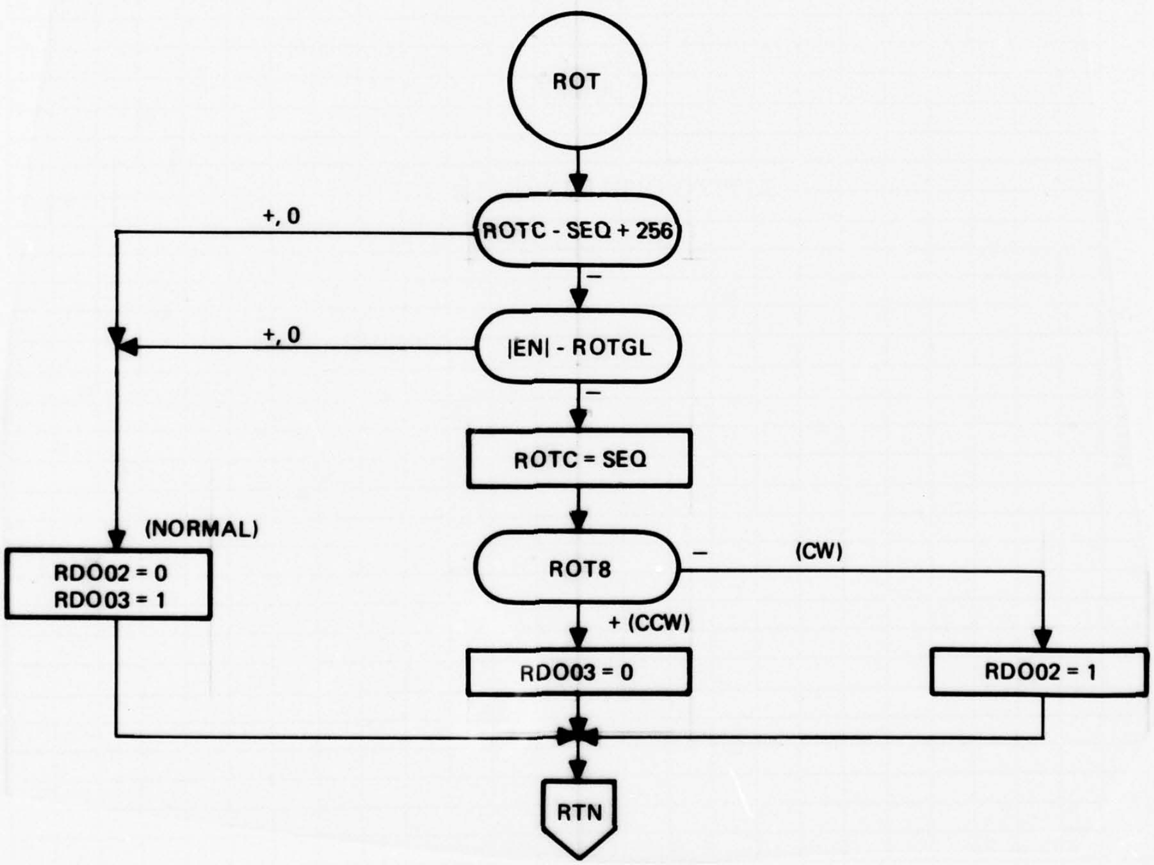


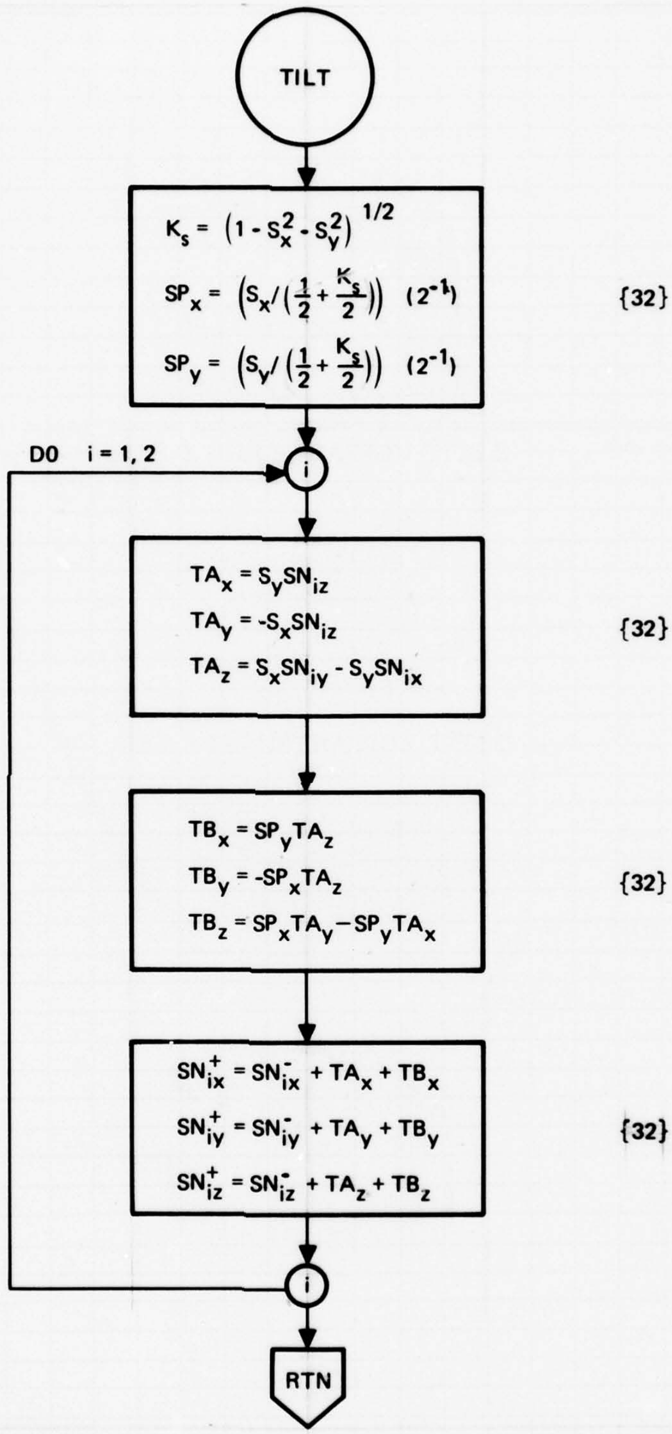
EXTRP(X)
$X_x^+ = X_x^- - 2^{-9}(T_B X_z^M - T_C X_y^M)$
$X_y^+ = X_y^- - 2^{-9}(T_C X_x^M - T_A X_z^M)$
$X_z^+ = X_z^- - 2^{-9}(T_A X_y^M - T_B X_x^M)$
RTN
(ALL $\{32 = 32 + (16)(16)\}$ BITS)

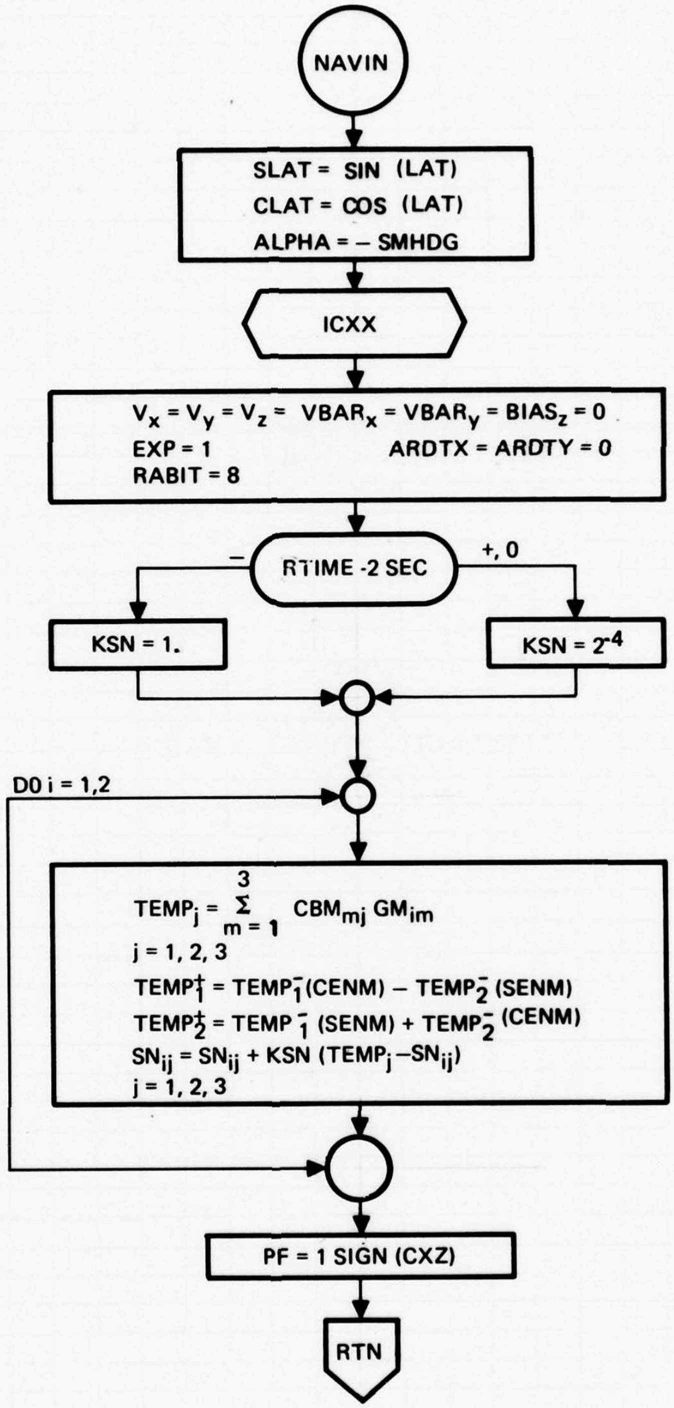

DC OFF
DAL$_{ij}$ = DAL$_{ij}$ + (DCG) (AL$_{ij}$ & X'FFF8 − DAL$_{ij}$)
DBT$_{ij}$ = DBT$_{ij}$ + (DCG) (BT$_{ij}$ & X'FFF8 − DBT$_{ij}$)
j = 1, 2, 3
i = 1, 2
RTN

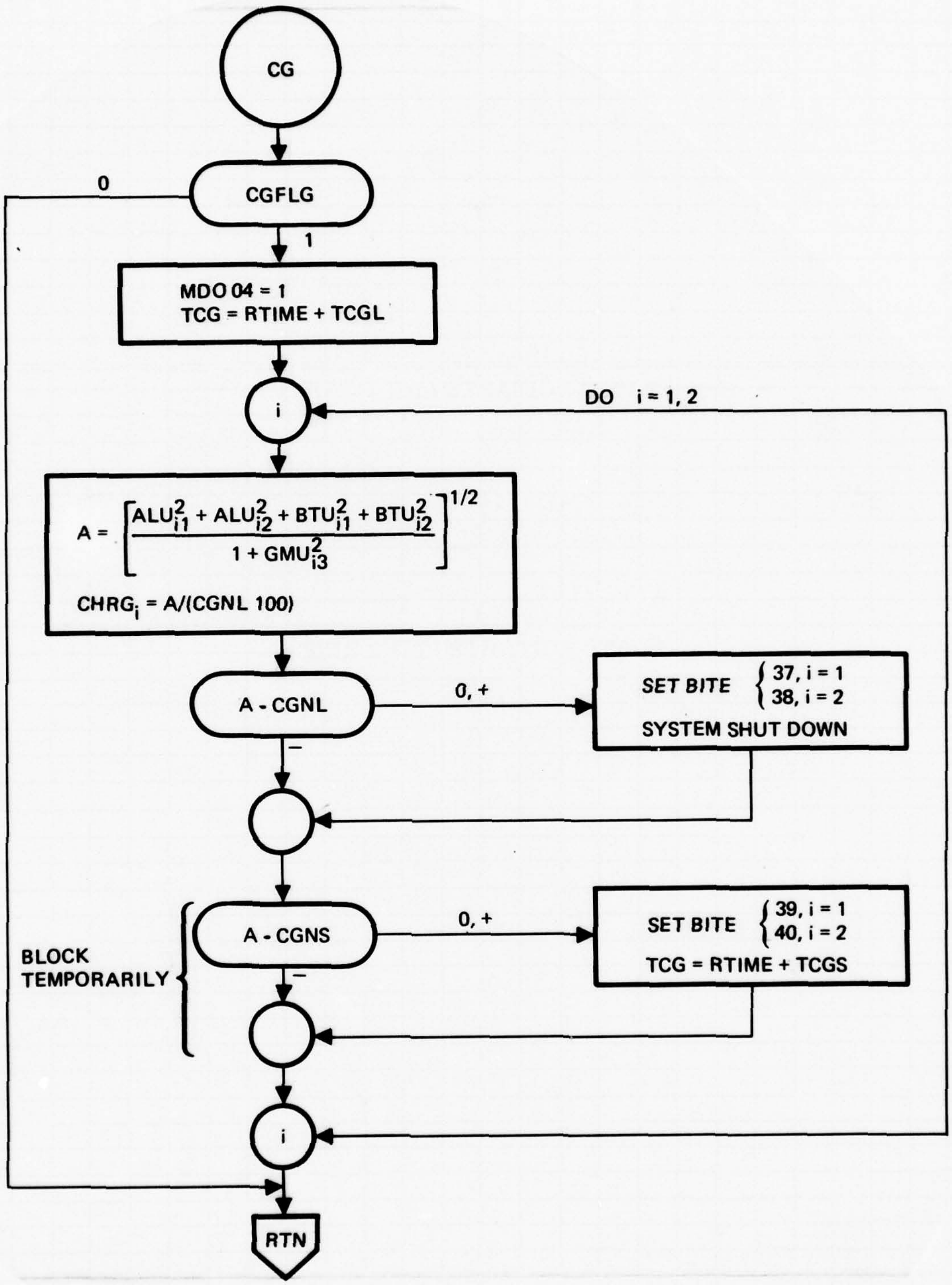

VCON
(VELOCITY CONTROL GOES HERE)
CNTF & B2
0
V = V + ΔV
VN = (V_X COSAL - V_Y SINAL) VSCL(2)
VE = (-V_X SINAL - V_Y COSAL) VSCL (2)
VD = -V_Z (VSCL) 2
VG = (VN^2 + VE^2)^1/2
RN = LAT - LATC
RE = (LON - LONC) CLAT
RTN

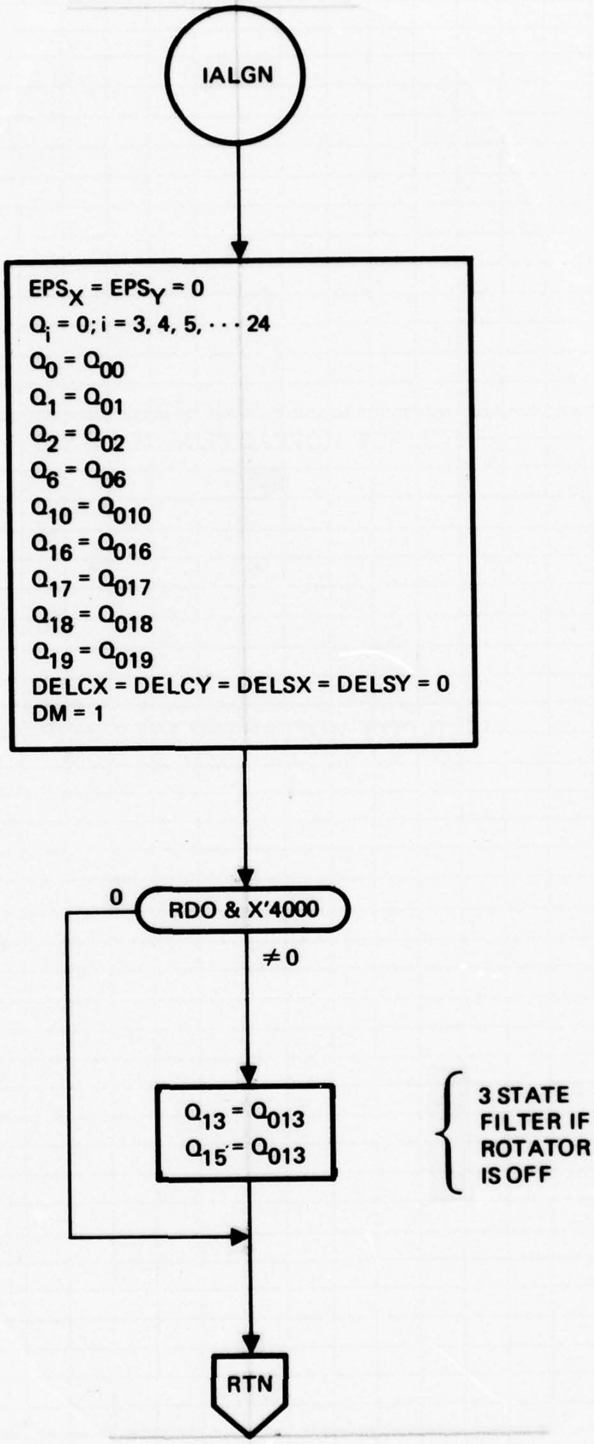

ICXX
SINAL = SIN (ALPHA)
COSAL = COS (ALPHA)
CXX = (CLAT) (COSAL)
CXY = -(CLAT) (SINAL)
CXZ = (SLAT)
RTN

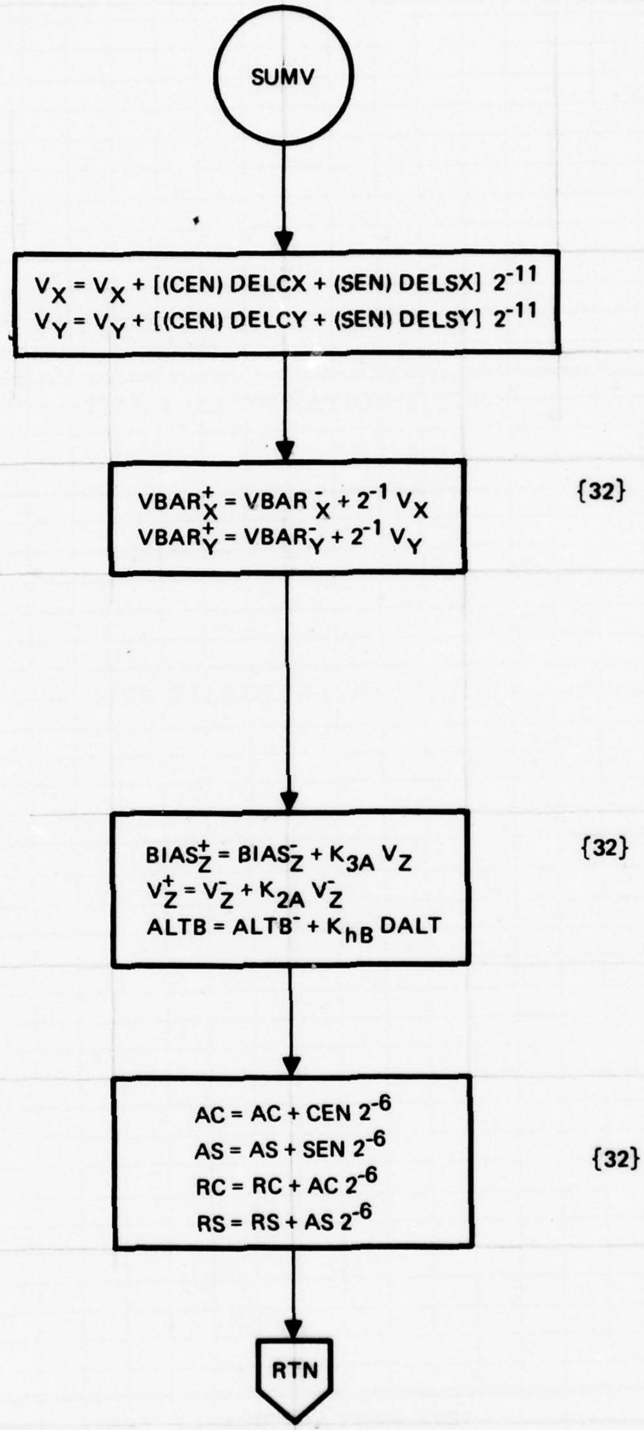

ROT
ROTC - SEQ + 256
+, 0
−
|EN| - ROTGL
+, 0
−
ROTC = SEQ
(NORMAL)
RDO02 = 0
RDO03 = 1
ROT8
−
(CW)
+ (CCW)
RDO03 = 0
RDO02 = 1
RTN


TILT
$K_s = \left(1 - S_x^2 - S_y^2\right)^{1/2}$
$SP_x = \left(S_x / \left(\frac{1}{2} + \frac{K_s}{2}\right)\right) \quad (2^{-1})$
$SP_y = \left(S_y / \left(\frac{1}{2} + \frac{K_s}{2}\right)\right) \quad (2^{-1})$
{32}
DO i = 1, 2
i
$TA_x = S_y SN_{iz}$
$TA_y = -S_x SN_{iz}$
$TA_z = S_x SN_{iy} - S_y SN_{ix}$
{32}
$TB_x = SP_y TA_z$
$TB_y = -SP_x TA_z$
$TB_z = SP_x TA_y - SP_y TA_x$
{32}
$SN_{ix}^{+} = SN_{ix}^{-} + TA_x + TB_x$
$SN_{iy}^{+} = SN_{iy}^{-} + TA_y + TB_y$
$SN_{iz}^{+} = SN_{iz}^{-} + TA_z + TB_z$
{32}
i
RTN


NAVIN
SLAT = SIN (LAT)
CLAT = COS (LAT)
ALPHA = – SMHDG
ICXX
$V_x = V_y = V_z =$ $VBAR_x = VBAR_y = BIAS_z = 0$
EXP = 1
ARDTX = ARDTY = 0
RABIT = 8
RTIME -2 SEC
–
+, 0
KSN = 1.
KSN = 2^{-4}
D0 i = 1,2
$TEMP_j = \sum_{m=1}^{3} CBM_{mj}\, GM_{im}$
j = 1, 2, 3
$TEMP_1^+ = TEMP_1^-(CENM) - TEMP_2^-(SENM)$
$TEMP_2^+ = TEMP_1^-(SENM) + TEMP_2^-(CENM)$
$SN_{ij} = SN_{ij} + KSN\,(TEMP_j - SN_{ij})$
j = 1, 2, 3
PF = 1 SIGN (CXZ)
RTN


CG
CGFLG
0
1
MDO 04 = 1
TCG = RTIME + TCGL
i
DO i = 1, 2
A = [(ALU²i1 + ALU²i2 + BTU²i1 + BTU²i2) / (1 + GMU²i3)]^1/2
CHRGi = A/(CGNL 100)
A - CGNL
0, +
SET BITE 37, i = 1 / 38, i = 2
SYSTEM SHUT DOWN
–
BLOCK TEMPORARILY
A - CGNS
0, +
SET BITE 39, i = 1 / 40, i = 2
TCG = RTIME + TCGS
–
i
RTN


IALGN
$EPS_X = EPS_Y = 0$
$Q_i = 0; i = 3, 4, 5, \cdots 24$
$Q_0 = Q_{00}$
$Q_1 = Q_{01}$
$Q_2 = Q_{02}$
$Q_6 = Q_{06}$
$Q_{10} = Q_{010}$
$Q_{16} = Q_{016}$
$Q_{17} = Q_{017}$
$Q_{18} = Q_{018}$
$Q_{19} = Q_{019}$
DELCX = DELCY = DELSX = DELSY = 0
DM = 1
0
RDO & X'4000
$\neq 0$
$Q_{13} = Q_{013}$
$Q_{15} = Q_{013}$
3 STATE FILTER IF ROTATOR IS OFF
RTN

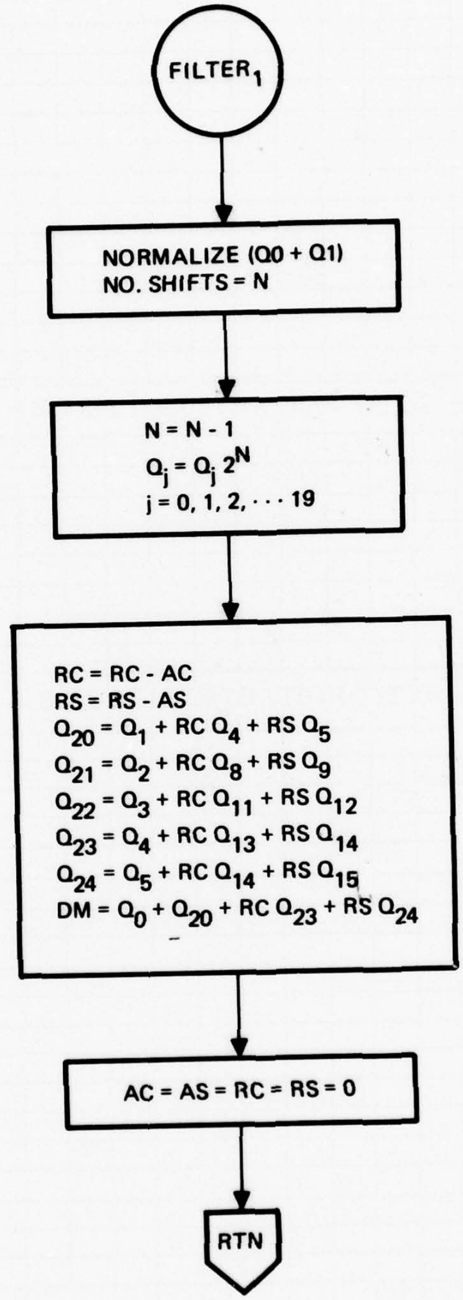

SUMV
$V_X = V_X + [(CEN)\ DELCX + (SEN)\ DELSX]\ 2^{-11}$
$V_Y = V_Y + [(CEN)\ DELCY + (SEN)\ DELSY]\ 2^{-11}$
$VBAR_X^+ = VBAR_X^- + 2^{-1}\ V_X$
$VBAR_Y^+ = VBAR_Y^- + 2^{-1}\ V_Y$
{32}
$BIAS_Z^+ = BIAS_Z^- + K_{3A}\ V_Z$
$V_Z^+ = V_Z^- + K_{2A}\ V_Z^-$
$ALTB = ALTB^- + K_{hB}\ DALT$
{32}
$AC = AC + CEN\ 2^{-6}$
$AS = AS + SEN\ 2^{-6}$
$RC = RC + AC\ 2^{-6}$
$RS = RS + AS\ 2^{-6}$
{32}
RTN

FILTER

$$Q_1 = Q_1 + 2\,Q_2 + (AC)\,Q_4 + (AS)\,Q_5$$
$$Q_2 = Q_2 + 2\,Q_6 + (AC)\,Q_8 + (AS)\,Q_9$$
$$Q_3 = Q_3 + 2\,Q_7 + (AC)\,Q_{11} + (AS)\,(Q_{12})$$
$$Q_4 = Q_4 + 2\,Q_8 + (AC)\,Q_{13} + (AS)\,Q_{14}$$
$$Q_5 = Q_5 + 2\,Q_9 + (AC)\,Q_{14} + (AS)\,Q_{15}$$
$$Q_6 = Q_6 + 2^{-4}\,Q_7$$
$$Q_7 = Q_7 + 2^{-4}\,Q_{10}$$
$$Q_8 = Q_8 + 2^{-4}\,Q_{11}$$
$$Q_9 = Q_9 + 2^{-4}\,Q_{12}$$
$$Q_1 = Q_1 + 2\,Q_2 + (AC)\,Q_4 + (AS)\,Q_5 + Q_{16} + Q_{17}$$
$$Q_2 = Q_2 + 2^{-4}\,Q_3$$
$$Q_6 = Q_6 + 2^{-4}\,Q_7 + Q_{18}\,2^{-6}$$
$$Q_{10} = Q_{10} + Q_{19}\,2^{-5}$$
$$Q_{16} = K_T\,Q_{16}$$

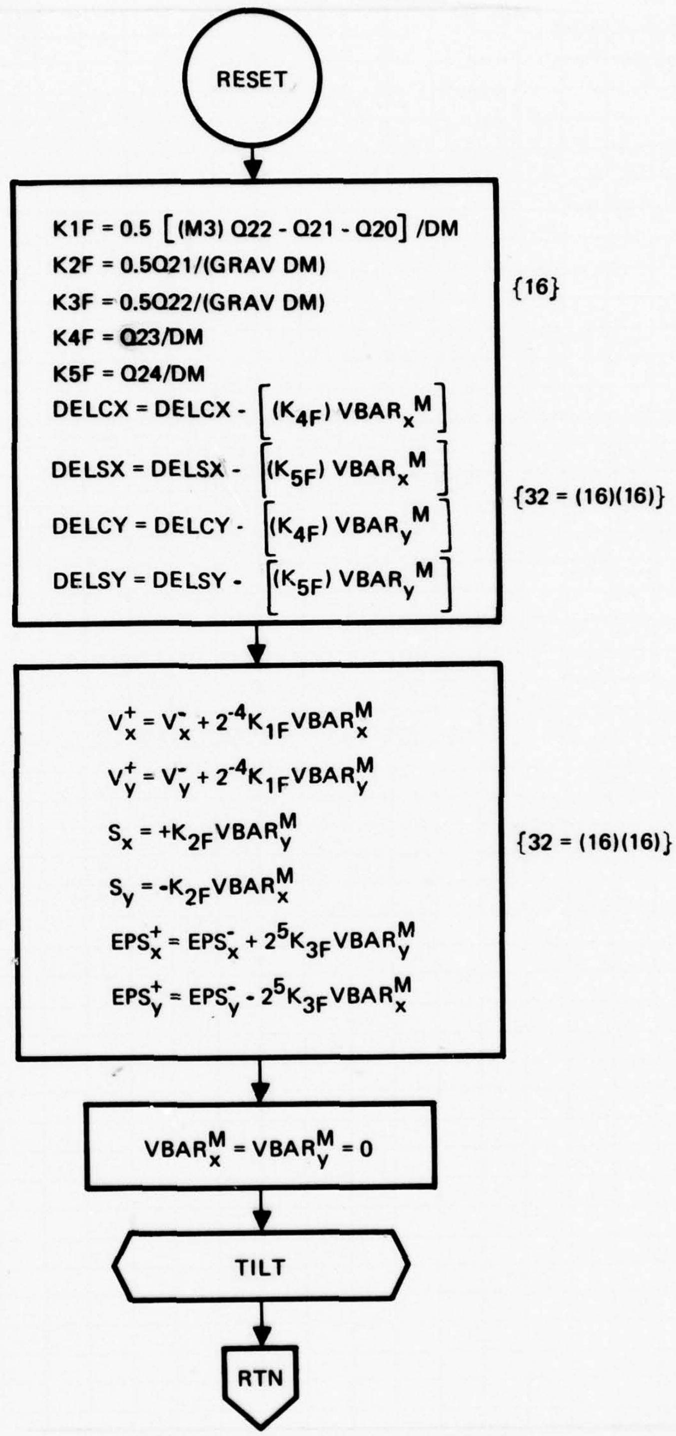
{32 BIT}

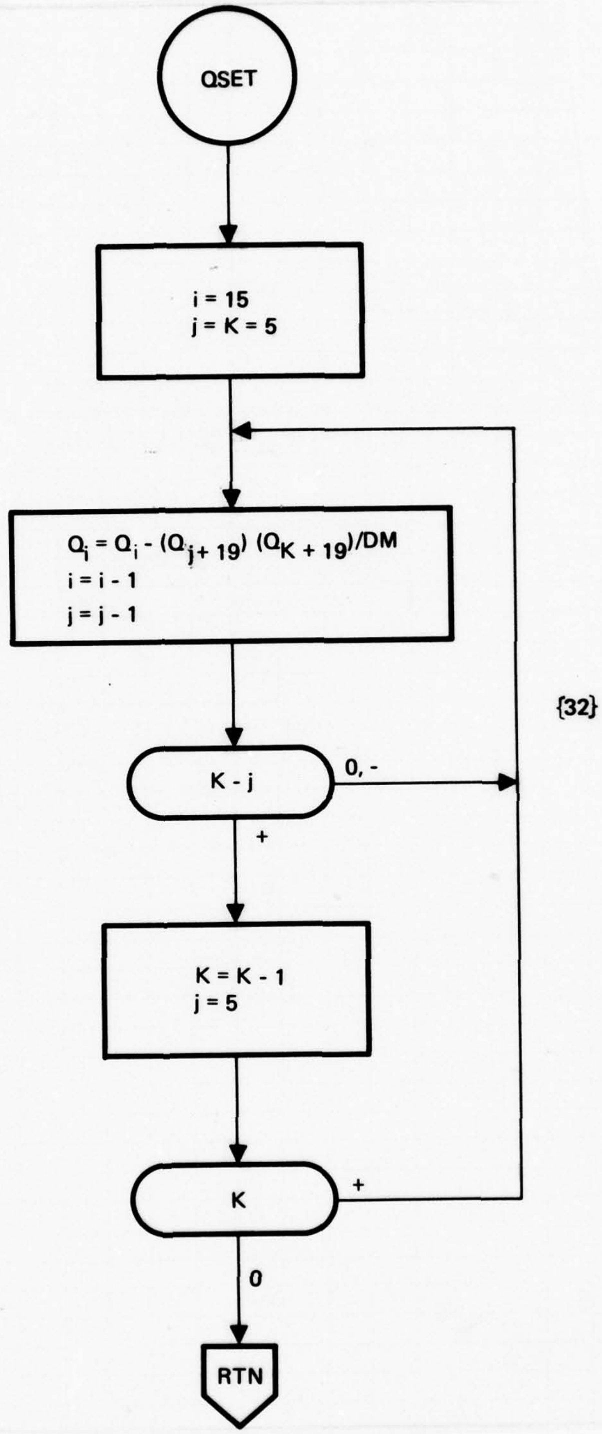
FILTER_1

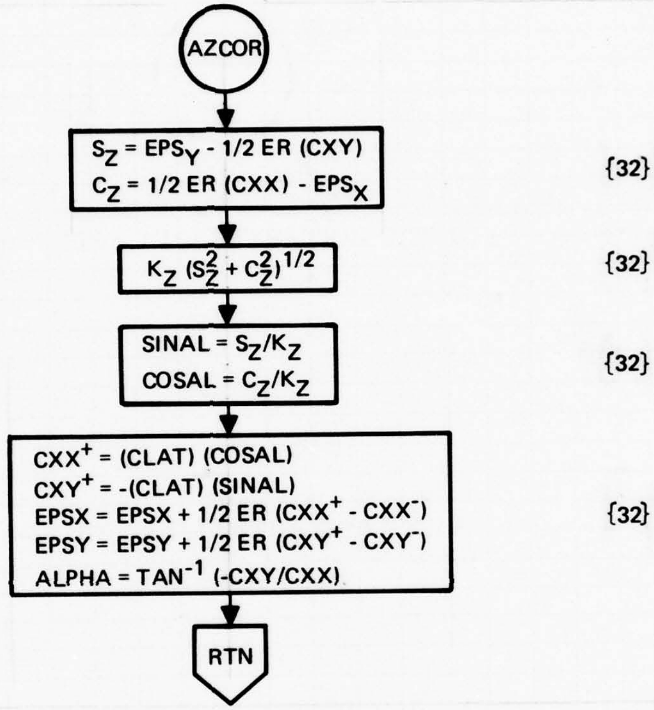


NOTE: 2^N CAN VARY FROM 2^{-1} TO 2^{+14}

{32}


RESET
K1F = 0.5 [(M3) Q22 - Q21 - Q20] /DM
K2F = 0.5Q21/(GRAV DM)
K3F = 0.5Q22/(GRAV DM)
K4F = Q23/DM
K5F = Q24/DM
{16}
$DELCX = DELCX - \left[(K_{4F})\ VBAR_x{}^M\right]$
$DELSX = DELSX - \left[(K_{5F})\ VBAR_x{}^M\right]$
$DELCY = DELCY - \left[(K_{4F})\ VBAR_y{}^M\right]$
$DELSY = DELSY - \left[(K_{5F})\ VBAR_y{}^M\right]$
{32 = (16)(16)}
$V_x^+ = V_x^- + 2^{-4} K_{1F} VBAR_x^M$
$V_y^+ = V_y^- + 2^{-4} K_{1F} VBAR_y^M$
$S_x = +K_{2F} VBAR_y^M$
$S_y = -K_{2F} VBAR_x^M$
$EPS_x^+ = EPS_x^- + 2^5 K_{3F} VBAR_y^M$
$EPS_y^+ = EPS_y^- - 2^5 K_{3F} VBAR_x^M$
{32 = (16)(16)}
$VBAR_x^M = VBAR_y^M = 0$
TILT
RTN


QSET
i = 15
j = K = 5
$Q_i = Q_i - (Q_{j+19})(Q_{K+19})/DM$
i = i - 1
j = j - 1
{32}
K - j
0, -
+
K = K - 1
j = 5
K
+
0
RTN


AZCOR
$S_Z = EPS_Y - 1/2\ ER\ (CXY)$
$C_Z = 1/2\ ER\ (CXX) - EPS_X$
{32}
$K_Z\ (S_Z^2 + C_Z^2)^{1/2}$
{32}
$SINAL = S_Z/K_Z$
$COSAL = C_Z/K_Z$
{32}
$CXX^+ = (CLAT)\ (COSAL)$
$CXY^+ = -(CLAT)\ (SINAL)$
$EPSX = EPSX + 1/2\ ER\ (CXX^+ - CXX^-)$
$EPSY = EPSY + 1/2\ ER\ (CXY^+ - CXY^-)$
$ALPHA = TAN^{-1}\ (-CXY/CXX)$
{32}
RTN

ATUDE

$$GMB_{ij} = \sum_{m=1}^{3} CBM_{mj}\ GMU_{im},\ j = 1, 2, 3,\ i = 1, 2$$

$$GMB_3 = GMB_1 \otimes GMB_2$$

$$CBN_{kj} = \sum_{i=1}^{3} CE_{ki}\ GMB_{ij}$$

(k, j) = (1, 1), (2, 1), (3, 1) (3,2) (3,3) ONLY

CEN = cos (EN + ENO - ROT8/2)

SEN = sin (EN + ENO - ROT8/2)

$$CBN_{31}^{+} = (CBN_{31}^{-})(CEN) - (CBN_{32}^{-})(SEN)$$

$$CBN_{32}^{+} = (CBN_{31}^{-})(SEN) + (CBN_{32}^{-})(CEN)$$

$$ROL = \tan^{-1}(CBN_{32}/(CBN_{33} + (PITO1)(CBN_{31}))) + ROLO$$

CR = cos (ROL), SR = sin (ROL)

$$PIT = TAN^{-1}(CBN_{31}/(CBN_{11}^{2} + CBN_{21}^{2})^{1/2}) - CR\ PITO$$

CP = cos (PIT), SP = sin (PIT)

HDO = (SR) (PITO)/CP

CR = CR (0.96), SR = SR(.96), CP = CP(0.96), SP = SP(0.96)

MODF: $\neq 3$ → RTN; 3 ↓

$$HDG = \tan^{-1}(-CBN_{21}/CBN_{11}) - ALPHA + EN + ENO - HDO - ROT8/2$$

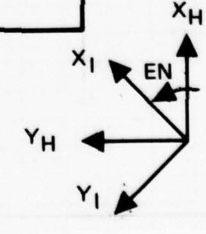
SH = sin (HDG) (0.96)

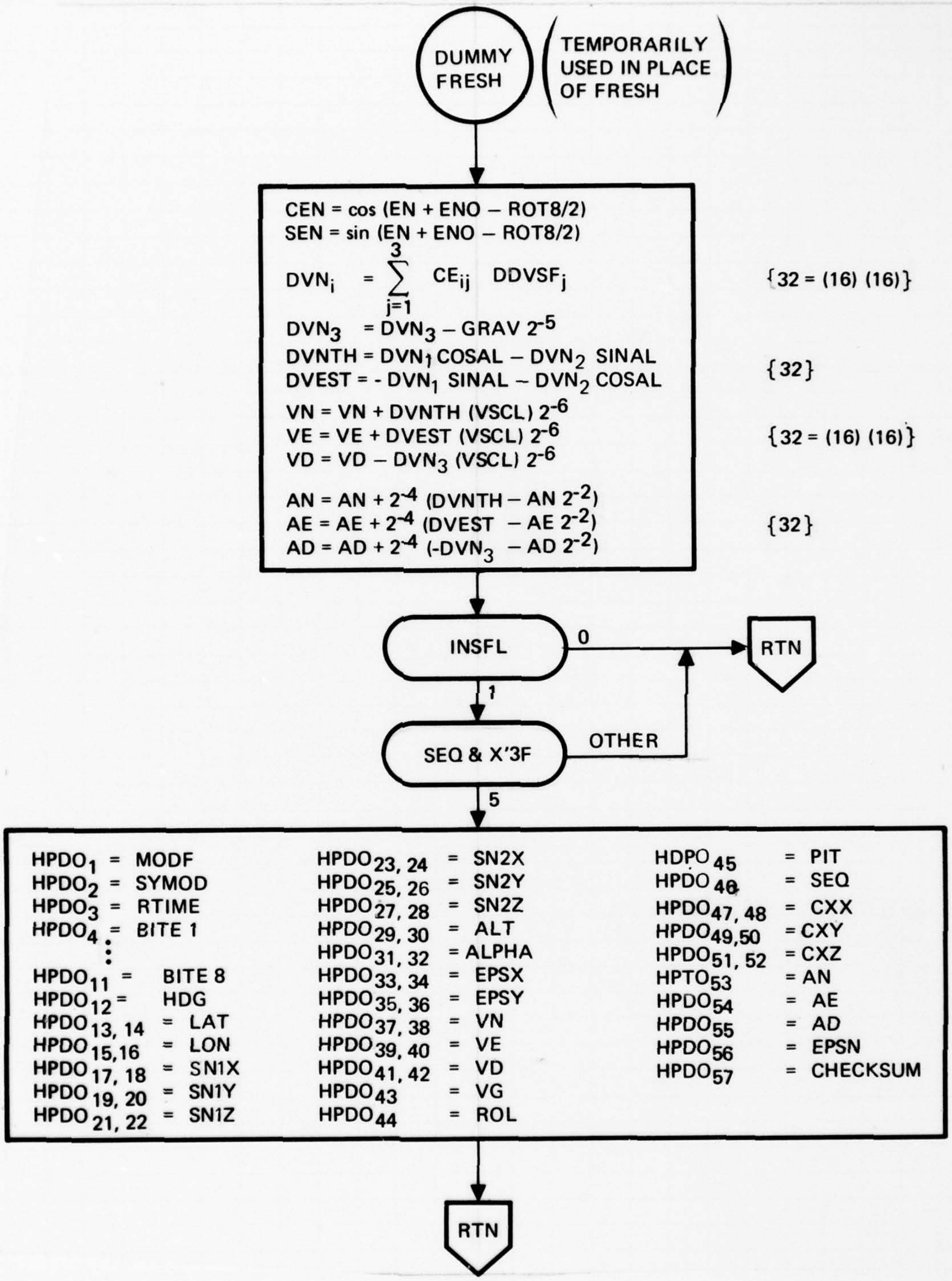
CH = cos (HDG) (0.96)

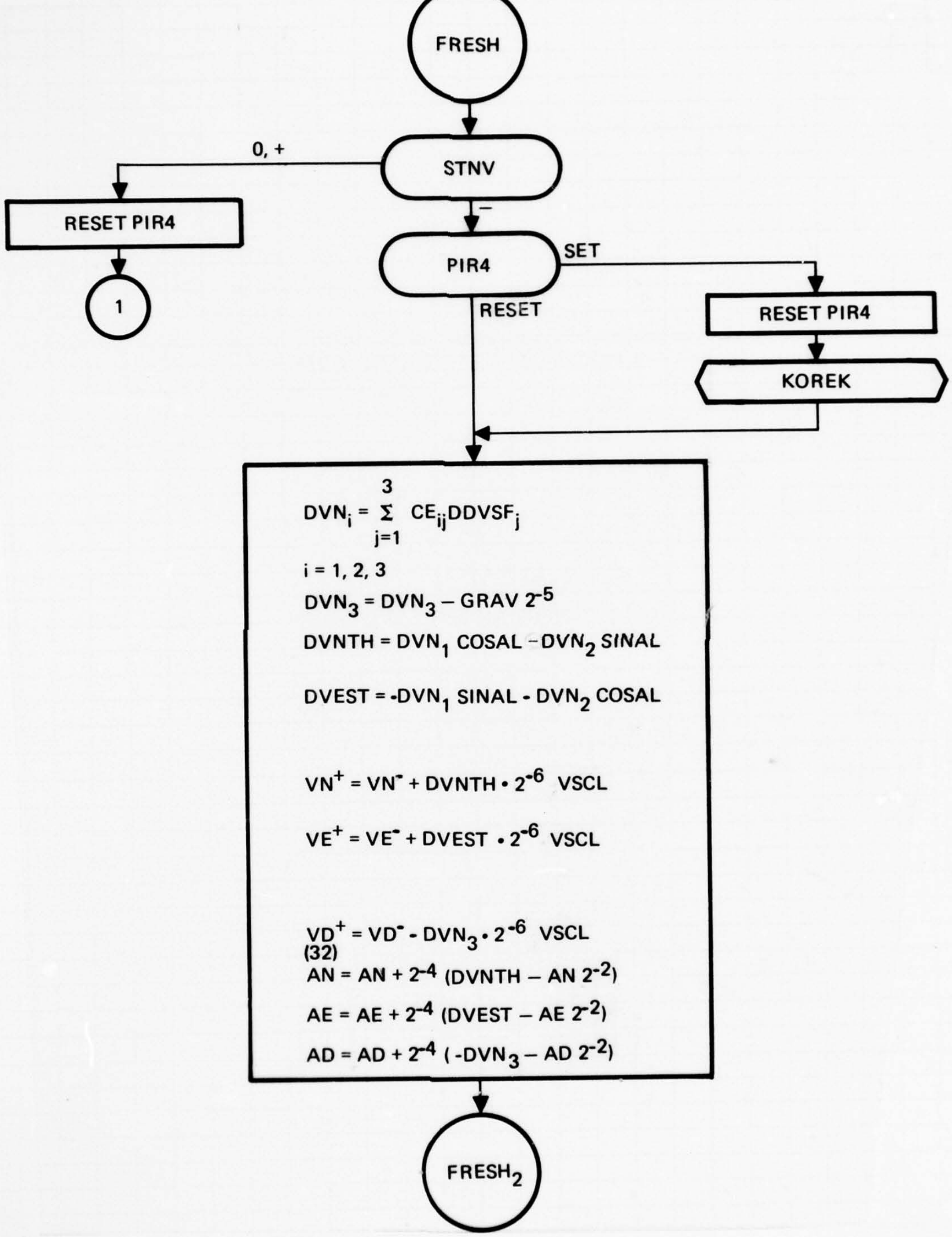
$$SMHDG = SMHDG - 2^{-8}(SMHDG - HDG)$$

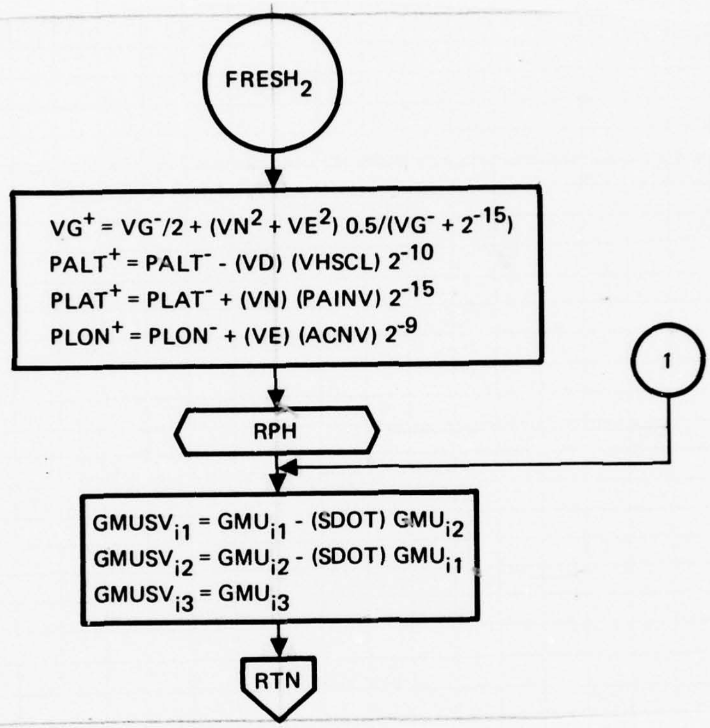
RTN

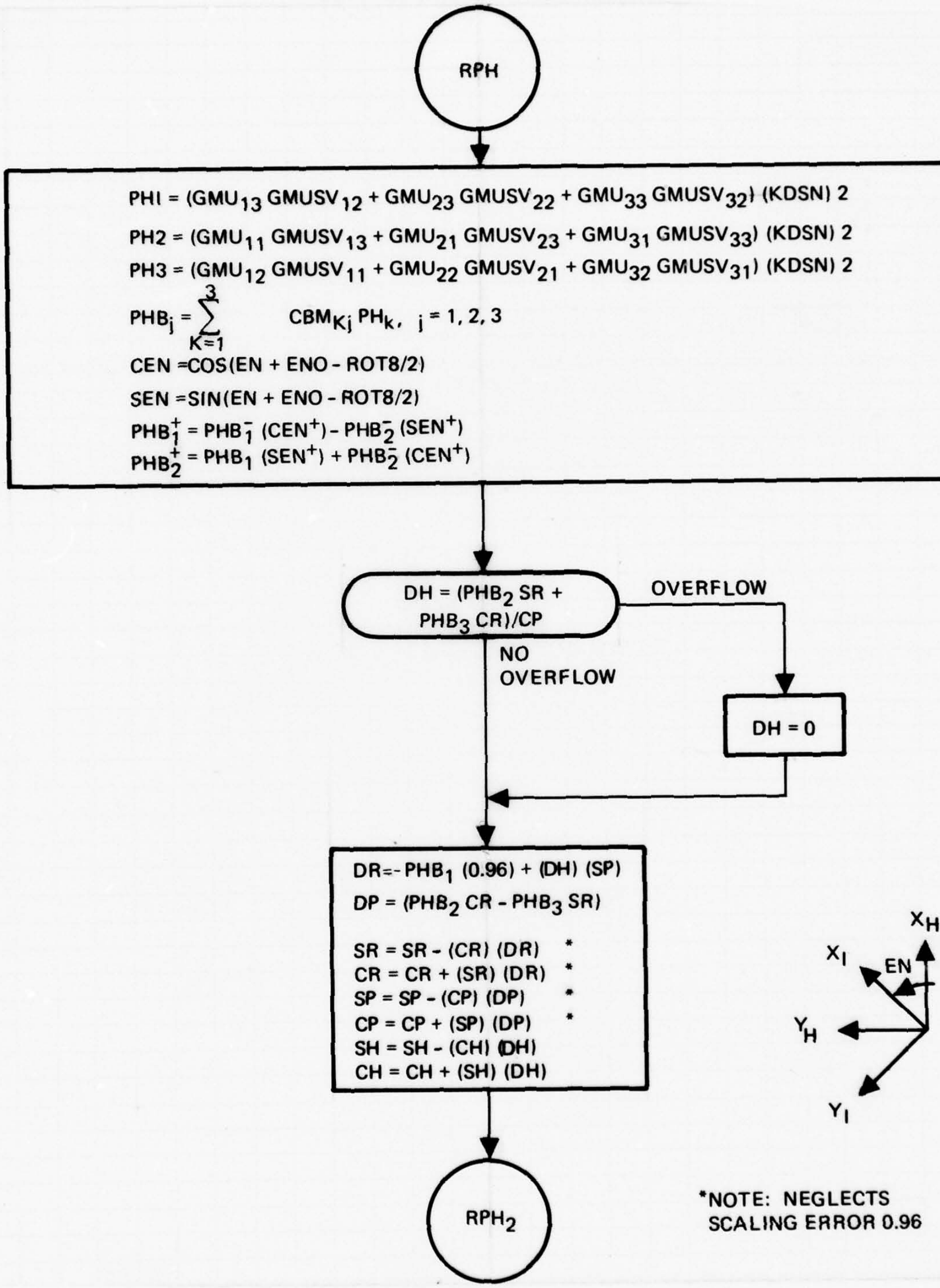
$$\left\{ (B_{HOUSING}) \xrightarrow{ROLO,\ PITO,\ EN} (B_{INST}) \xrightarrow{CBM} (M) \xrightarrow{\gamma} (S) \xrightarrow{CSN} (N) \right\}$$

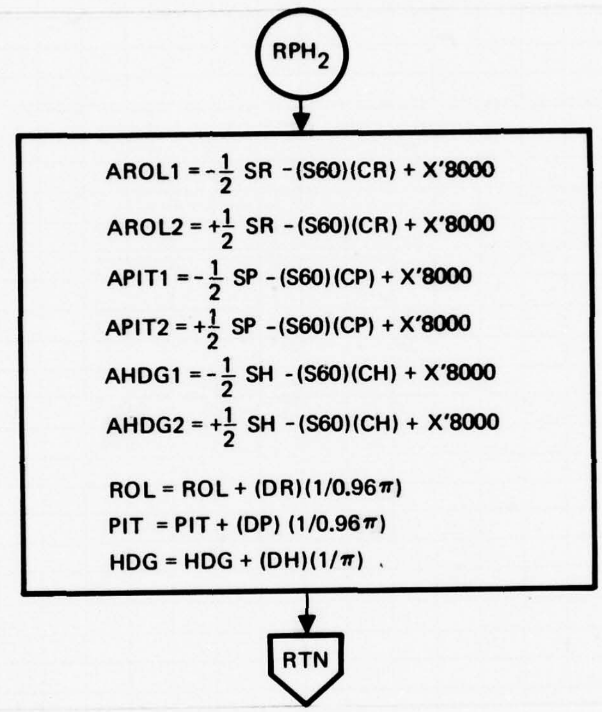


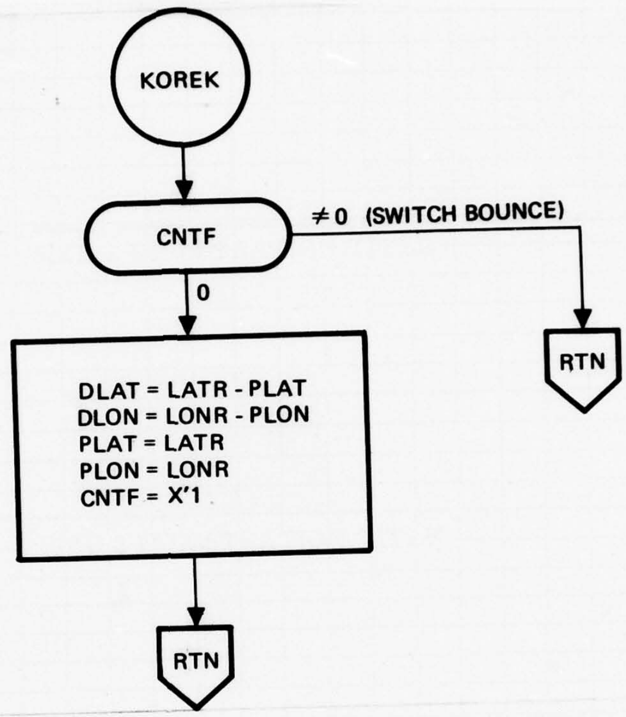

DUMMY FRESH
TEMPORARILY USED IN PLACE OF FRESH
CEN = cos (EN + ENO – ROT8/2)
SEN = sin (EN + ENO – ROT8/2)
$DVN_i = \sum_{j=1}^{3} CE_{ij}\ DDVSF_j$
{32 = (16) (16)}
$DVN_3 = DVN_3 - GRAV\ 2^{-5}$
$DVNTH = DVN_1\ COSAL - DVN_2\ SINAL$
$DVEST = - DVN_1\ SINAL - DVN_2\ COSAL$
{32}
$VN = VN + DVNTH\ (VSCL)\ 2^{-6}$
$VE = VE + DVEST\ (VSCL)\ 2^{-6}$
$VD = VD - DVN_3\ (VSCL)\ 2^{-6}$
{32 = (16) (16)}
$AN = AN + 2^{-4}\ (DVNTH - AN\ 2^{-2})$
$AE = AE + 2^{-4}\ (DVEST - AE\ 2^{-2})$
$AD = AD + 2^{-4}\ (-DVN_3 - AD\ 2^{-2})$
{32}
INSFL
0
1
RTN
SEQ & X'3F
OTHER
5
$HPDO_1$ = MODF
$HPDO_2$ = SYMOD
$HPDO_3$ = RTIME
$HPDO_4$ = BITE 1
$HPDO_{11}$ = BITE 8
$HPDO_{12}$ = HDG
$HPDO_{13, 14}$ = LAT
$HPDO_{15,16}$ = LON
$HPDO_{17, 18}$ = SN1X
$HPDO_{19, 20}$ = SN1Y
$HPDO_{21, 22}$ = SN1Z
$HPDO_{23, 24}$ = SN2X
$HPDO_{25, 26}$ = SN2Y
$HPDO_{27, 28}$ = SN2Z
$HPDO_{29, 30}$ = ALT
$HPDO_{31, 32}$ = ALPHA
$HPDO_{33, 34}$ = EPSX
$HPDO_{35, 36}$ = EPSY
$HPDO_{37, 38}$ = VN
$HPDO_{39, 40}$ = VE
$HPDO_{41, 42}$ = VD
$HPDO_{43}$ = VG
$HPDO_{44}$ = ROL
$HDPO_{45}$ = PIT
$HPDO_{46}$ = SEQ
$HPDO_{47, 48}$ = CXX
$HPDO_{49,50}$ = CXY
$HPDO_{51, 52}$ = CXZ
$HPTO_{53}$ = AN
$HPDO_{54}$ = AE
$HPDO_{55}$ = AD
$HPDO_{56}$ = EPSN
$HPDO_{57}$ = CHECKSUM
RTN

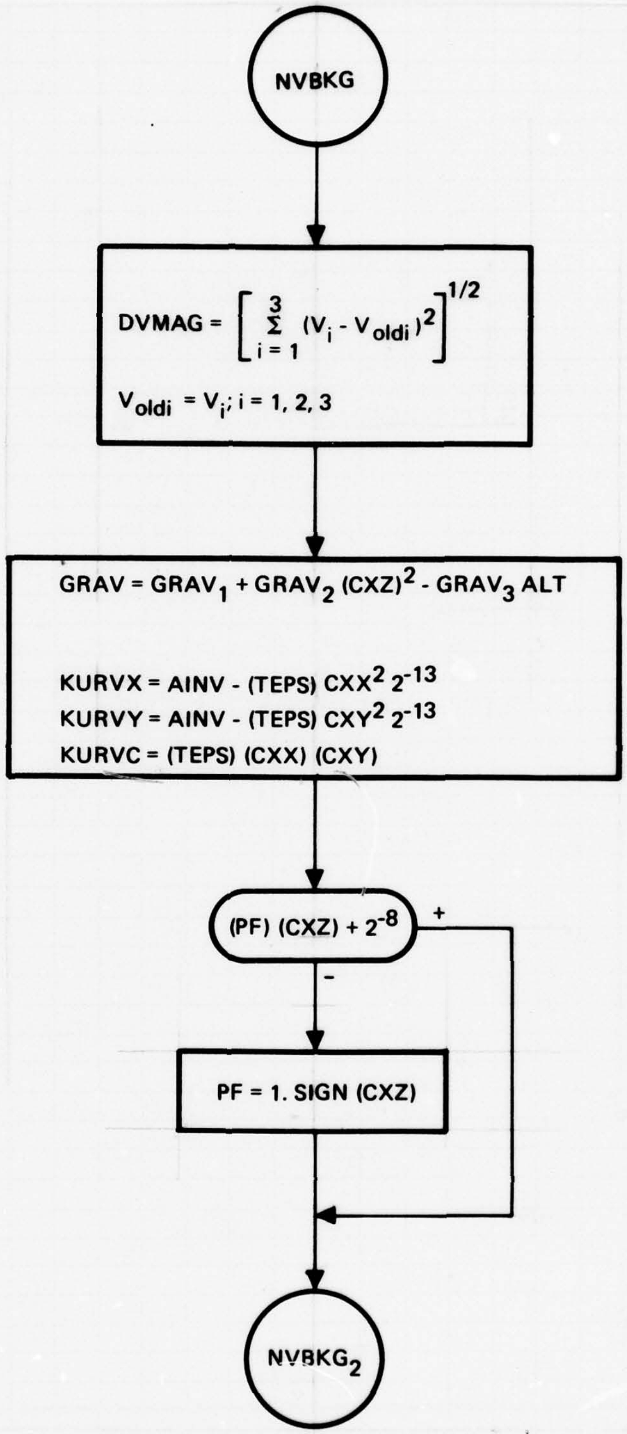

FRESH
STNV
0, +
RESET PIR4
1
–
PIR4
SET
RESET
RESET PIR4
KOREK
$DVN_i = \sum_{j=1}^{3} CE_{ij} DDVSF_j$
$i = 1, 2, 3$
$DVN_3 = DVN_3 - GRAV\ 2^{-5}$
$DVNTH = DVN_1\ COSAL - DVN_2\ SINAL$
$DVEST = -DVN_1\ SINAL - DVN_2\ COSAL$
$VN^+ = VN^- + DVNTH \cdot 2^{-6}\ VSCL$
$VE^+ = VE^- + DVEST \cdot 2^{-6}\ VSCL$
$VD^+ = VD^- - DVN_3 \cdot 2^{-6}\ VSCL$
(32)
$AN = AN + 2^{-4}\ (DVNTH - AN\ 2^{-2})$
$AE = AE + 2^{-4}\ (DVEST - AE\ 2^{-2})$
$AD = AD + 2^{-4}\ (-DVN_3 - AD\ 2^{-2})$
$FRESH_2$


$FRESH_2$
$VG^+ = VG^-/2 + (VN^2 + VE^2)\ 0.5/(VG^- + 2^{-15})$
$PALT^+ = PALT^- - (VD)\ (VHSCL)\ 2^{-10}$
$PLAT^+ = PLAT^- + (VN)\ (PAINV)\ 2^{-15}$
$PLON^+ = PLON^- + (VE)\ (ACNV)\ 2^{-9}$
1
RPH
$GMUSV_{i1} = GMU_{i1} - (SDOT)\ GMU_{i2}$
$GMUSV_{i2} = GMU_{i2} - (SDOT)\ GMU_{i1}$
$GMUSV_{i3} = GMU_{i3}$
RTN


RPH
$PH1 = (GMU_{13}\,GMUSV_{12} + GMU_{23}\,GMUSV_{22} + GMU_{33}\,GMUSV_{32})\,(KDSN)\,2$
$PH2 = (GMU_{11}\,GMUSV_{13} + GMU_{21}\,GMUSV_{23} + GMU_{31}\,GMUSV_{33})\,(KDSN)\,2$
$PH3 = (GMU_{12}\,GMUSV_{11} + GMU_{22}\,GMUSV_{21} + GMU_{32}\,GMUSV_{31})\,(KDSN)\,2$
$PHB_j = \sum_{K=1}^{3} CBM_{Kj}\,PH_k, \quad j = 1, 2, 3$
$CEN = COS(EN + ENO - ROT8/2)$
$SEN = SIN(EN + ENO - ROT8/2)$
$PHB_1^+ = PHB_1^-\,(CEN^+) - PHB_2^-\,(SEN^+)$
$PHB_2^+ = PHB_1\,(SEN^+) + PHB_2^-\,(CEN^+)$
$DH = (PHB_2\,SR + PHB_3\,CR)/CP$
OVERFLOW
NO OVERFLOW
DH = 0
$DR = -PHB_1\,(0.96) + (DH)\,(SP)$
$DP = (PHB_2\,CR - PHB_3\,SR)$
SR = SR - (CR) (DR) *
CR = CR + (SR) (DR) *
SP = SP - (CP) (DP) *
CP = CP + (SP) (DP) *
SH = SH - (CH) (DH)
CH = CH + (SH) (DH)
RPH_2
X_H
X_I
EN
Y_H
Y_I
*NOTE: NEGLECTS SCALING ERROR 0.96


RPH_2
AROL1 = $-\frac{1}{2}$ SR − (S60)(CR) + X'8000
AROL2 = $+\frac{1}{2}$ SR − (S60)(CR) + X'8000
APIT1 = $-\frac{1}{2}$ SP − (S60)(CP) + X'8000
APIT2 = $+\frac{1}{2}$ SP − (S60)(CP) + X'8000
AHDG1 = $-\frac{1}{2}$ SH − (S60)(CH) + X'8000
AHDG2 = $+\frac{1}{2}$ SH − (S60)(CH) + X'8000
ROL = ROL + (DR)(1/0.96π)
PIT = PIT + (DP) (1/0.96π)
HDG = HDG + (DH)(1/π)
RTN


KOREK
CNTF
≠0 (SWITCH BOUNCE)
0
RTN
DLAT = LATR - PLAT
DLON = LONR - PLON
PLAT = LATR
PLON = LONR
CNTF = X'1
RTN


NVBKG
$DVMAG = \left[\sum_{i=1}^{3} (V_i - V_{oldi})^2 \right]^{1/2}$
$V_{oldi} = V_i; i = 1, 2, 3$
$GRAV = GRAV_1 + GRAV_2 (CXZ)^2 - GRAV_3 ALT$
$KURVX = AINV - (TEPS) CXX^2 2^{-13}$
$KURVY = AINV - (TEPS) CXY^2 2^{-13}$
$KURVC = (TEPS) (CXX) (CXY)$
$(PF) (CXZ) + 2^{-8}$
+
-
PF = 1. SIGN (CXZ)
$NVBKG_2$

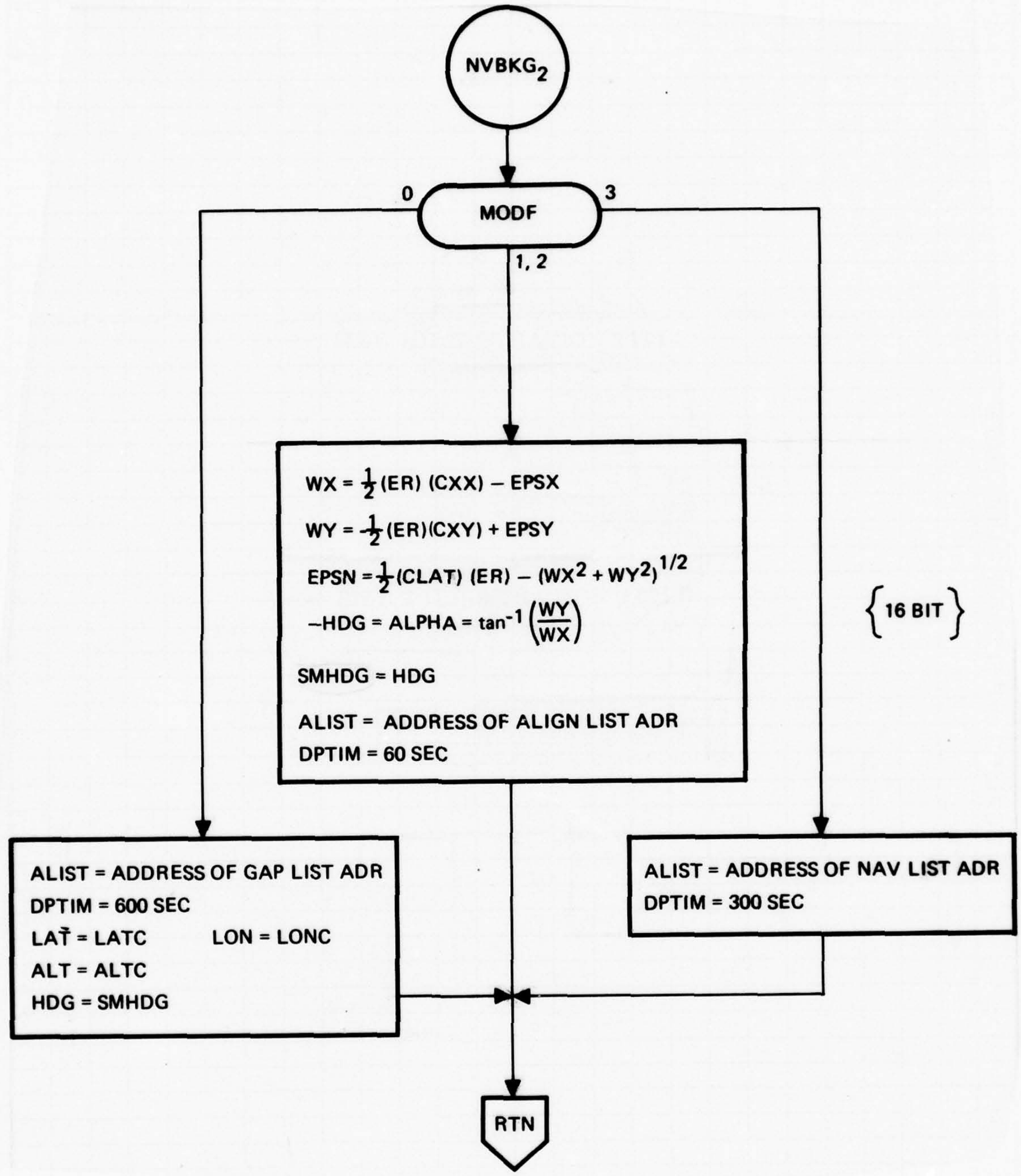

NVBKG2
MODF
0
3
1, 2
WX = 1/2 (ER) (CXX) − EPSX
WY = −1/2 (ER)(CXY) + EPSY
EPSN = 1/2 (CLAT) (ER) − (WX² + WY²)^1/2
−HDG = ALPHA = tan⁻¹ (WY/WX)
SMHDG = HDG
ALIST = ADDRESS OF ALIGN LIST ADR
DPTIM = 60 SEC
{16 BIT}
ALIST = ADDRESS OF GAP LIST ADR
DPTIM = 600 SEC
LAT = LATC
LON = LONC
ALT = ALTC
HDG = SMHDG
ALIST = ADDRESS OF NAV LIST ADR
DPTIM = 300 SEC
RTN

TABLE K-1. NAVIGATION PROGRAM CONSTANTS

Symbol	Definition	Value	Max Value	Scaled Value
AINV (32 Bit)	1/8 sec * Inverse of Earth Radius (Equatorial)	$\Delta t_s/20925604$ ft	2^{-21} fps^{-1}	0.012527374
ER (32 Bit)	Earth Rate	7.292116^{-5} rad/sec	2^{-13} rad/sec	0.59737014
K_{1h}	Vertical Damping – Altitude ($3\Delta t_s/\tau$) (τ = 100 sec, ζ = 0.7)	$0.03\ \Delta t_s$	2^{-8}	0.96
K_{2h}	Vertical Damping – Velocity $(1/\zeta^2 + 2)\ \Delta t_s/\tau^2 + 2w_s^2 \Delta t_s$	$(4^{-4} + 2w_s^2)\ \Delta t_s$	2^{-14}/sec	0.82549
K_{3h}	Vertical Damping – Bias ($\Delta t_s/\tau^3\zeta^2$)	$-2^{-6}\ \Delta t_s$	$2^{-20}/\text{sec}^2$	-0.262144
K_{hB}	Altimeter Biasing – Align (τ = 64 sec)	$2^{-6}\ \Delta t_s$	1	2^{-9}
K_{2A}	Vertical Channel Align – Velocity ($2\Delta t_s/\tau$) (τ = 64 sec, ζ = 0.7)	$-2^{-5}\ \Delta t_s$	1	-2^{-8}
K_{3A}	Vertical Channel Align – Bias ($\Delta t_s/\tau^2\zeta^2$)	$2^{-11}\ \Delta t_s$	2^{-6}/sec	2^{-8}
K_{CAGE}	Redundant Axis Caging ($\tau = 2^8$ sec)	-2^{-8}/sec	2^{-7}/sec	-2^{-1}
K_e	Gyro Bias Decay Gain (τ = 2 hr)	$\Delta t_s/7200$	2^{-6}	1.11^{-3}
LGAIN	DC Offset Filter – Low Gain ($\tau = 2^6$ sec)	$2^{-6}\ \Delta t_s$	1	2^{-9}
HGAIN	DC Offset Filter – High Gain (τ = 2 sec)	$2\ \Delta t_s$	1	2^{-2}
Q_{00}	Measurement Noise	$(2^{-6}\ \text{fps})^2$	$2^6\ (\text{fps})^2$	2^{-18}
Q_{01}	Initial Cov – (Vel, Vel)	$33\ (\text{fps})^2$	$2^6\ (\text{fps})^2$	0.515625
Q_{02}	Inital Cov – (Vel, Tilt)	–	$2^4/g$ rad fps	-0.5
Q_{06}	Initial Cov – (Tilt, Tilt)	$(2.52\ \text{deg})^2$	$2^2/g^2\ \text{rad}^2$	0.5
Q_{010}	Initial Cov – (Drift, Drift)	$(0.52\ \text{deg/hr})^2$	$2^{-12}/g^2\ (\text{rad/sec})^2$	0.00002724

TABLE K-1. (Cont)

Symbol	Definition	Value	Max Value	Scaled Value
Q_{013}	Initial Cov – (∇, ∇)	0.17 mrad	$(1\ fps^2/g)^2$	$3.16{\star}^{-5}$
Q_{017}	Process Noise – (Vel)	$(0.00391\ fps)^2$	$2^6\ (fps)^2$	2^{-22}
Q_{018}	Process Noise – (Tilt)	$(6.7{\star}^{-7}\ rad)^2$	$2^{-4}/g^2\ (rad)^2$	2^{-27}
Q_{019}	Process Noise – (Drift)	$(3.88{\star}^{-4}\ deg/hr)^2$	$2^{-18}/g^2\ (rad/sec)^2$	2^{-30}
Q_{016}	Process Noise – (Thermal-Vel)	$\approx 2^{-14}\ (fps)^2$	$2^6\ (fps)^2$	$1.192{\star}^{-6}$
K_T	Thermal Noise Decay Gain (τ = 75 sec)	0.898825	1	0.898825
SEQF	Course Align Time	2^5 sec	2^{-6} sec (LSB)	2^{11}
NF	Fine Align Time – Minimum	5 min	2^{-6} sec (LSB)	19200
NSH	Stored Heading Time – Minimum	2^6 sec	2^{-6} sec (LSB)	2^{12}
TCGL	Time Between Charge Monitor (Long)	3600 sec	1 sec (LSB)	3600.
TCGS	Time Between Charge Monitor (Short)	1800 sec	1 sec (LSB)	1800.
VTURN	Max Velocity Change in 1 sec for Charge Monitor	10 fps	2^{12} fps	0.00244
CGNL	Large Charge Threshold	TBD	1	TBD
CGNS	Small Charge Threshold	TBD	1	TBD
$GRAV_1$ (32 Bit)	Gravity Coefficient	$32.088032\ fps^2$	$2^6\ fps^2$	0.5013755
$GRAV_2$ (32 Bit)	Gravity Coefficient	$0.1696944\ fps^2$	$2^6\ fps^2$	0.002651475
$GRAV_3$ (32 Bit)	Gravity Coefficient	$3.085610{\star}^{-6}/sec^2$	$2^{-11}/sec^2$	0.006319341
MAGC	GMU Magnitude Correction	$(4.76)\ 2^{-16}$	2^{-5}	0.00232

TABLE K-1. (Concluded)

Symbol	Definition	Value	Max Value	Scaled Value
VSCL	Scaling to Velocity Display	2^{12} fps/2500 fps	2	0.8192
TEPS	Earth Ellipticity $(2\epsilon/a)\ \Delta t_s$	4.005^{-11} fps^{-1}	2^{-34} fps^{-1}	0.688054
VHSCL	Scaling to Altitude Display Extrapolation	4.85988^{-4}	2^{-10}	0.49765
PAINV	1/64 sec * Inverse Earth Radius – Display	2^{-6} sec/20925604 ft	$(\pi/2500$ fps$)\ 2^{-15}$	0.0194706
HSCL	Scaling to Altitude Display	2^{17} ft/80337.5 ft	2	0.81535
KVA	Velocity Scaling for Drift Comp	-0.7957031	1	-0.7957031
ROTGL	Rotator Turn Around Threshold	0.69 deg	π rad	0.00383
M3	Align Filter Measurement Coefficient $gT^2/6$	$g\ 2^5/3$	$g\ 2^9$	0.0208333

TABLE K-2. NAVIGATION PROGRAM VARIABLES

Symbol	Index i	Index j	Definition	Max Value	Word Length (Bits)
MODC	–	–	Mode Command-Control/Display Panel 0 = Standby 1 = Stored Heading (Cal) 2 = Gyro Compass (Align) 3 = Nav	–	16
MODF	–	–	Functioning Mode (Same Code as MODC)	–	16
RTIME	–	–	1 sec Clock	2^{15} sec	16
STDSV	–	–	Status Display Word to Control/Display Panel	–	16
CGFLG	–	–	Charge Monitor Flag, ≠ 0 Charge Monitor in Progress	–	16
TCG	–	–	Value of RTIME for Next Scheduled Charge Monitor	2^{15} sec	16
DVMAG	–	–	Velocity Change Over 1 sec Interval	2^{12} fps	16
LATC	–	–	Initial Latitude (Keyboard Input)	π	32
LONC	–	–	Initial Longitude (Keyboard Input)	π	32
LATR	–	–	Check Point Latitude	π	32
LONR	–	–	Check Point Longitude	π	32

TABLE K-2. (Cont)

Symbol	Index i	Index j	Definition	Max Value	Word Length (Bits)
GMG_{ij}	Gyro (1, 2, 3)	Axis (1, 2, 3)	Uncompensated γ (γ_{Gi})-Gyro Frame	1	16
GGD	–	–	$GMG_1 \cdot GMG_2$	1	16
DGG	–	–	$1 - GGD^2$	1	16
GD_{ij}	Gyro (1, 2)	(1, 2, 3, 4)	$DG_{i1} = \Delta\gamma_i \cdot \Delta\gamma_i + (2^{-12} - 2^{-16})$ $DG_{i2} = \gamma_{GK} \cdot \Delta\gamma_i \; (K \neq i)$ $DG_{i3} = \gamma_{G3} \cdot \Delta\gamma_i / DGG$ $DG_{i4} = DG_{i2}/DGG$	2^{-5} rad	16
GM_{ij}	Gyro (1, 2, 3)	Axis (1, 2, 3)	Compensated γ (γ_{Ci})-MICRON Frame	1	32
ET_{ij}	Row (1, 2, 3)	Column (1, 2, 3)	Delta Velocity Correction Matrix (η)	2^{-5} rad	16
ETO_{ij}	Row (1, 2, 3)	Column (1, 2, 3)	Old ET Matrix	2^{-5} rad	16
$GMGC_{ij}$	Gyro (1, 2, 3)	Axis (1, 2, 3)	Compensated γ-Gyro Coordinates (γ_{Gi})	1	16
DVM_i	Axis (1, 2, 3)	–	Delta Velocity From Fast Cycle $DVUB_i$ MICRON Coordinates	2^7 fps	16
EXP	–	–	Exponential Decay	1	32
BS_{ij}	Gyro (1, 2)	Axis (1, 2, 3)	Drift Rate Compensation Spin Frame	2^{-15} rad/sec	16
DVS_i	Axis (1, 2, 3)	–	Compensated Delta Velocity-Spin Frame	2^7 fps	32
GM_{DOT}	–	–	$GM_1 \cdot GM_2$ Filtered	1	32
D_{DOT}	–	–	$GM_{DOT} + S_{DOT}$	1	32
V_i	Axis (1, 2, 3)	–	Velocity	2^{12} fps	32

TABLE K-2. (Cont)

Symbol	Index		Definition	Max Value	Word Length (Bits)
	i	j			
SN_{ij}	Gyro (1, 2, 3)	Axis (1, 2, 3)	RSA Vectors – Nav Frame	1	32
S_{DOT}	–	–	$-SN_1 \cdot SN_2$	1	32
DSN	–	–	$1 - S^2_{DOT}$	1	32
KDSN	–	–	1/DSN	2	32
CX_i	Axis (x, y, z)	–	Earth Polar Direction Cosines	1	32
$ERDT_i$	Axis (1, 2, 3)	–	ER_i * 1/8 sec + Residual	2^{-9} rad	32
$THDT_{ij}$	Gyro (1, 2)	Axis (1, 2, 3)	Drift Angle Change Over 1/8 sec + Residual	2^{-9} rad	32
$ARDT_i$	Axis (1, 2)	–	Vehicle Rate * 1/8 sec + Residual	2^{-9} rad	32
ALT	–	–	Altitude	2^{17} ft	32
ALTR	–	–	Reference Altitude (Input)	TBD	16
ALTB	–	–	Reference Altitude Bias	2^{17} ft	32
DALT	–	–	Altitude Error	2^{17} ft	16
BIASZ	–	–	Vertical Accelerometer Bias	2^6 fps^2	32
GRAV	–	–	Gravity	2^6 fps^2	32

TABLE K-2. (Cont)

Symbol	Index i	Index j	Definition	Max Value	Word Length (Bits)
ALPHA	–	–	Angle From North to X Nav Axis (CCW)	π rad	32
LAT	–	–	Latitude	π rad	32
LON	–	–	Longitude	π rad	32
$C_{SN_{ij}}$	Row (1, 2, 3)	Column (1, 2, 3)	Spin to Nav Transformation Matrix	1	16
CE_{ij}	Row (1, 2, 3)	Column (1, 2, 3)	Spin to Nav Transformation + ARO Correction Matrix	2 rad	16
GMB_{ij}	Gyro (1, 2, 3)	Axis (1, 2, 3)	Uncompensated γ-Body Frame	1	16
CBN_{ij}	Row (1, 2, 3)	Column (1, 2, 3)	Body to Nav Transformation Matrix [Only Compute (i,j) = (1,1), (2,1), (3,1), (3,2), (3,3)]	1	16
HDG	–	–	Heading (Load HDG = 0)	π rad	16
PIT	–	–	Pitch Angle	π rad	16
ROL	–	–	Roll Angle	π rad	16
EPS_i	Axis (1, 2)	–	Alignment Drift Rate Estimate	2^{-12} rad/sec	32
$VBAR_i$	Axis (1, 2)	–	Average Velocity	2^7 fps	32
Q_i	(0, 1, ... 19)	–	Covariance Matrix and Noise Variances	Relative Scale See Constants Q_{0i} for Initial Scale	32
K_{iF}	(1, 2, 3, 4, 5)	–	Alignment Reset Gains		
			K_{1F}	2	16
			K_{2F}	2^{-7} rad/fps	16
			K_{3F}	2^{-16} rad/sec/fps	16
			K_{4F}, K_{5F}	2^{-3} fps^2/fps	16
KURVX			Earth Curvature Terms	2^{-21} (fps)$^{-1}$	32
KURVY			$* 2^{-3}$ sec	2^{-21} (fps)$^{-1}$	32
KURVC				2^{-36} (fps)$^{-1}$	16

TABLE K-2. (Cont)

Symbol	Index		Definition	Max Value	Word Length (Bits)
	i	j			
VN, VE, VD	–	–	Velocity North, East, Down – Display	2500 fps	32
VG	–	–	Ground Speed	2500 fps	16
DVNTH, DVEST	–	–	Velocity Change 1/64 sec – North, East	2^5 fps	32
DVN_i	Axis (1, 2, 3)	–	Velocity Change 1/64 sec – Nav Frame	2^5 fps	32
AN, AE, AD	–	–	Acceleration North, East, Down	512 fps^2	32
PLAT, PLON	–	–	Display Latitude, Longitude	π rad	32
DLAT, DLON	–	–	Latitude, Longitude Check Point Correction	π rad	32
CNTF	–	–	Control Flag $\neq 0$ Means Apply Control in Slow Cycle Routines (LSB) Bit 15 – Position Control Bit 14 – Velocity Control Bit 13 – Tilt Control	–	16
PH_i	Axis (1, 2, 3)	–	Altitude Change – MICRON Frame	1 rad	16
PHB_i	Axis (1, 2, 3)	–	Altitude Change – Body Frame	1 rad	16
DR, DP	–	–	Roll, Pitch Change	1/0.96 rad	16
DH	–	–	Heading Change	1 rad	16
SR, CR, SP CP, SH, CH	–	–	Sin/Cos of Roll, Pitch, Heading	1/0.96	16

TABLE K-2. (Concluded)

Symbol	Index i	Index j	Definition	Max Value	Word Length (Bits)
ACNV	–	–	1/64 sec/(Earth Radius Cos Lat)	π/2500 fps 2^{-9}	16
SLAT, CLAT	–	–	Sin, Cos Latitude	1	32
SINAL, COSAL	–	–	Sin, Cos ALPHA	1	32
PF	–	–	Single Pole Flag + = South Pole Singularity - = North Pole Singularity	–	16
DELCX, DELSX, DELCY, DELSY	–	–	Rotating Bias Error Estimate – Align	2^4 sec	32
AC, AS	–	–	$\int_0^{8\ sec}$ Cos, Sin of Rotation Angle	2^3 sec	32
RC, RS	–	–	$\frac{1}{8\ sec}\int_0^{8}$ AC, AS dt	2^3 sec	32
CEN, SEN	–	–	Cos, Sin of Rotation Angle (EN)	1	16
ROT8	–	–	Rotation Angle in 1/64 sec	π rad	16
RN, RE	–	–	Distance From Initialization	π rad	16
EPSN	–	–	North Drift Rate For Display	2^{-12} rad/sec	16

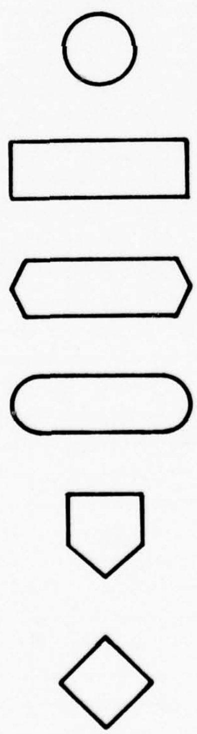
TABLE K-3. FIVE-STATE ALIGNMENT FILTER

Parameter	Value	Max Value		Scaled Value
		State Vector	Cov	
Q_0	$(0.5, -0.1\ \text{ft})^2 = 2^{-8}, -2^{-12}\ (\text{fps})^2$		$2^6\ (\text{fps})^2$	$2^{-14}, 2^{-18}$
Q_1	$(33\ \text{fps})^2$	2^3 fps	$2^6\ (\text{fps})^2$	0.515625
Q_2	(V, ϕ)		$2^4/g\ (\text{r-fps})$	-2^{-1}
Q_3	(V, ϵ)		$2^{-3}/g\ (\text{r/s} - \text{fps})$	0
Q_4	(V, ∇_c)		$2^3\ (\text{fps} - \text{fps}^2)$	0
Q_5	(V, ∇_s)		$2^3\ (\text{fps} \cdot \text{fps}^2)$	0
Q_6	$(2.52^\circ)^2 = 6.375^{\text{deg}^2}$ 0.0019322r^2	2/g rad	$2^2/g^2\ (\text{r}^2)$	2^{-1}
Q_7	(ϕ, ϵ)		$2^{-7}/g^2\ (\text{r}^2/\text{s})$	0
Q_8	(ϕ, ∇_c)		$2/g\ (\text{r} \cdot \text{fps}^2)$	0
Q_9	(ϕ, ∇_s)		$2/g\ (\text{r} \cdot \text{fps}^2)$	0
Q_{10}	$(\epsilon, \epsilon) = (0.52^\circ/\text{hr})^2$ $0.8^{-9}\ (\text{fps}3)^2$	$2^{-6}/g$ r/s	$2^{-12}/g^2\ (\text{r/s})^2$	$2.724^{-5} \approx 2^{-15}$
Q_{11}	(ϵ, ∇_c)		$2^{-6}/g\ (\text{r/s fps}^2)$	0
Q_{12}	(ϵ, ∇_s)		$2^{-6}/g\ (\text{r/s fps}^2)$	0
Q_{13}	$(\nabla_c, \nabla_c)\ (0.17\ \text{mr})^2\ g^2$	$1\ \text{fps}^2$	$1\ (\text{fps}^2)$	$3.16^{-5} \approx 2^{-15}$
Q_{14}	(∇_c, ∇_s)		$1\ (\text{fps}^2)^2$	0
Q_{15}	$(\nabla_s, \nabla_s)\ (0.17\ \text{mr})^2\ g^2$	$1\ \text{fps}^2$	$1\ (\text{fps}^2)^2$	$3.16^{-5} \approx 2^{-15}$
Q_{16}	$(\text{Therm V}) = 7.6^{-5}\ (\text{fps})^2 = 2^{-9}$		$2^6\ (\text{fps})^2$	$1.192^{-6} \approx 2^{-20}$
Q_{17}	$\text{V Noise} = 0.153^{-4}\ (\text{fps})^2 = 2^{-16}$		$2^6\ (\text{fps})^2$	2^{-22}
Q_{18}	$\phi\ \text{Noise} = 45^{-14}\ \text{r}^2 = 2^{-41}$		$2^{-4}/g^2\ (\text{r}^2)$	2^{-27}
Q_{19}	$\epsilon\ \text{Noise} = 14.7^{-8}\ (^\circ/\text{hr})^2$ $= 3.453^{-18}\ (\text{r/s})^2$		$2^{-18}/g^2\ (\text{r/s})^2$	2^{-30}

APPENDIX L

EPM SIMULATOR
DETAILED FLOW CHARTS

FLOW CHART SYMBOLS



ENTRY POINT OR CONNECTOR

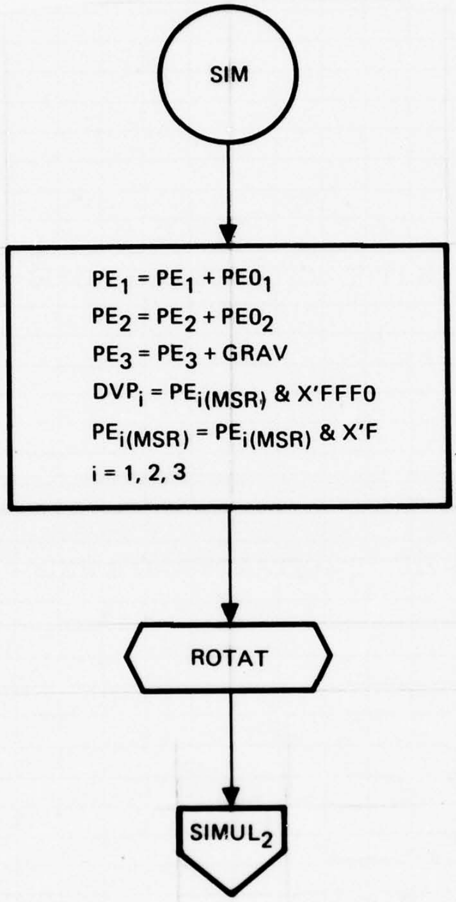
PROCESS

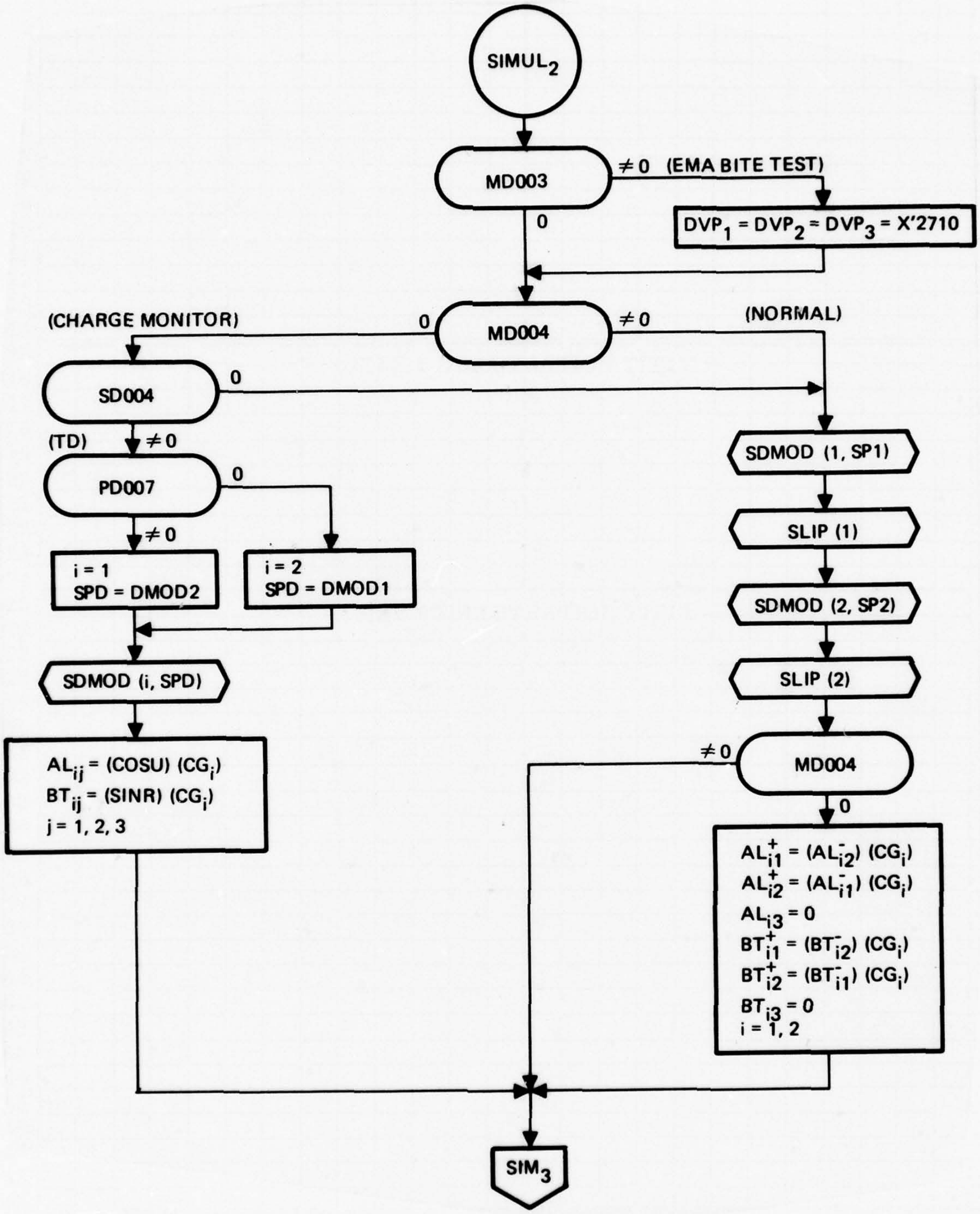
SUBROUTINE

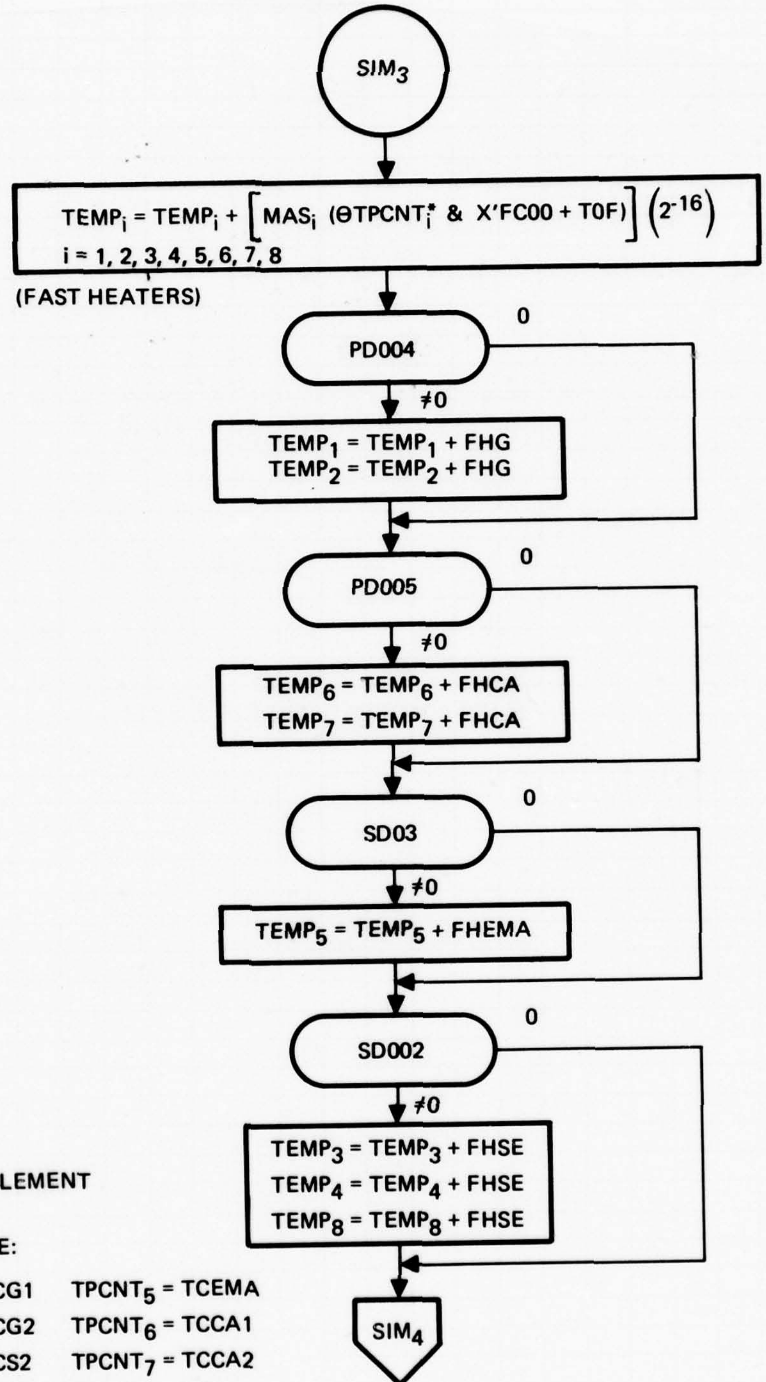
BRANCH POINT

OFF-PAGE CONNECTOR

OFF-PAGE BRANCH


SIM
$PE_1 = PE_1 + PE0_1$
$PE_2 = PE_2 + PE0_2$
$PE_3 = PE_3 + GRAV$
$DVP_i = PE_{i(MSR)}$ & X'FFF0
$PE_{i(MSR)} = PE_{i(MSR)}$ & X'F
$i = 1, 2, 3$
ROTAT
$SIMUL_2$

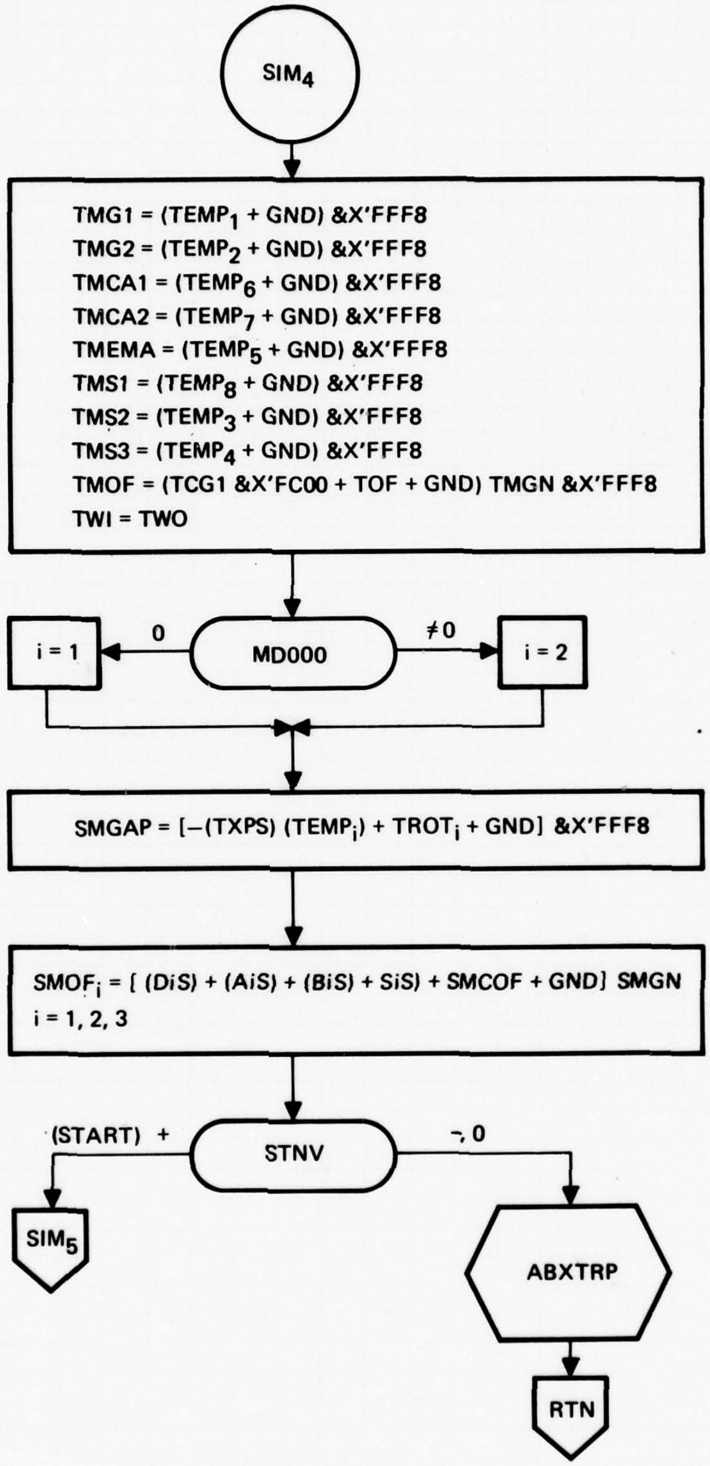

SIMUL2
MD003
≠0 (EMA BITE TEST)
0
DVP1 = DVP2 = DVP3 = X'2710
(CHARGE MONITOR)
0
MD004
≠0
(NORMAL)
SD004
0
(TD)
≠0
PD007
0
≠0
i = 1
SPD = DMOD2
i = 2
SPD = DMOD1
SDMOD (i, SPD)
ALij = (COSU) (CGi)
BTij = (SINR) (CGi)
j = 1, 2, 3
SDMOD (1, SP1)
SLIP (1)
SDMOD (2, SP2)
SLIP (2)
≠0
MD004
0
AL+i1 = (AL-i2) (CGi)
AL+i2 = (AL-i1) (CGi)
ALi3 = 0
BT+i1 = (BT-i2) (CGi)
BT+i2 = (BT-i1) (CGi)
BTi3 = 0
i = 1, 2
SIM3



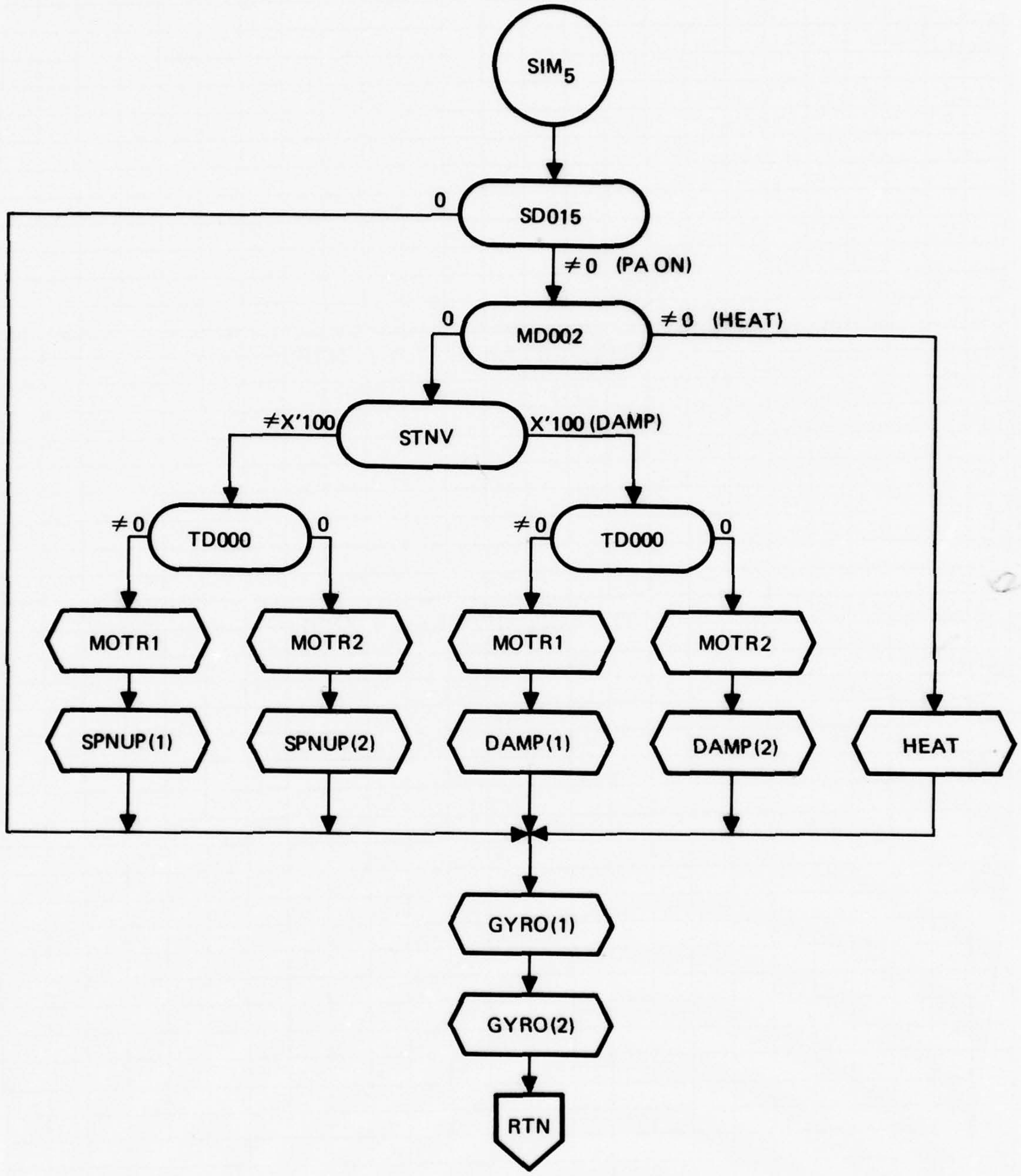
Θ = ONES COMPLEMENT

*EQUIVALENCE:

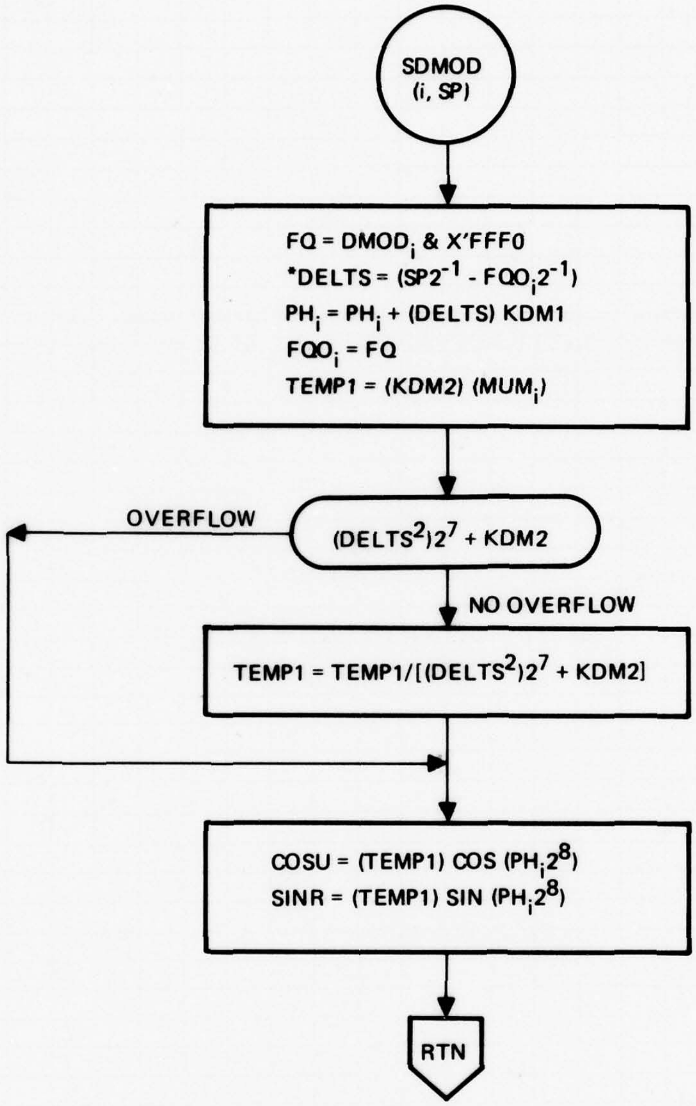
$TPCNT_1$ = TCG1	$TPCNT_5$ = TCEMA
$TPCNT_2$ = TCG2	$TPCNT_6$ = TCCA1
$TPCNT_3$ = TCS2	$TPCNT_7$ = TCCA2
$TPCNT_4$ = TCS3	$TPCNT_8$ = TCS1



SIM$_4$
TMG1 = (TEMP$_1$ + GND) &X'FFF8
TMG2 = (TEMP$_2$ + GND) &X'FFF8
TMCA1 = (TEMP$_6$ + GND) &X'FFF8
TMCA2 = (TEMP$_7$ + GND) &X'FFF8
TMEMA = (TEMP$_5$ + GND) &X'FFF8
TMS1 = (TEMP$_8$ + GND) &X'FFF8
TMS2 = (TEMP$_3$ + GND) &X'FFF8
TMS3 = (TEMP$_4$ + GND) &X'FFF8
TMOF = (TCG1 &X'FC00 + TOF + GND) TMGN &X'FFF8
TWI = TWO
i = 1
0
MD000
≠0
i = 2
SMGAP = [−(TXPS) (TEMP$_i$) + TROT$_i$ + GND] &X'FFF8
SMOF$_i$ = [(DiS) + (AiS) + (BiS) + SiS) + SMCOF + GND] SMGN
i = 1, 2, 3
(START) +
STNV
¬, 0
SIM$_5$
ABXTRP
RTN



SIM5
SD015
0
≠0 (PA ON)
MD002
0
≠0 (HEAT)
STNV
≠X'100
X'100 (DAMP)
TD000
≠0
0
TD000
≠0
0
MOTR1
MOTR2
MOTR1
MOTR2
SPNUP(1)
SPNUP(2)
DAMP(1)
DAMP(2)
HEAT
GYRO(1)
GYRO(2)
RTN



*NOTE: SP_i AND FQO_i HAVE NO SIGN BIT

SLIP(i)

$TA_j = (ALSIM_{ij})\,(COSU) + (BTSIM_{ij})\,(SINR)$

$TB_j = -(ALSIM_{ij})\,(SINR) + (BTSIM_{ij})\,(COSU)$

$j = 1, 2, 3$

$TA_1^{+} = (TA_1^{-})\,CROT + (TA_2^{-})\,SROT$

$TA_2 = -(TA_1^{-})\,SROT + (TA_2^{-})\,CROT$

$TB_1^{+} = (TB_1^{-})\,CROT + (TB_2^{-})\,SROT$

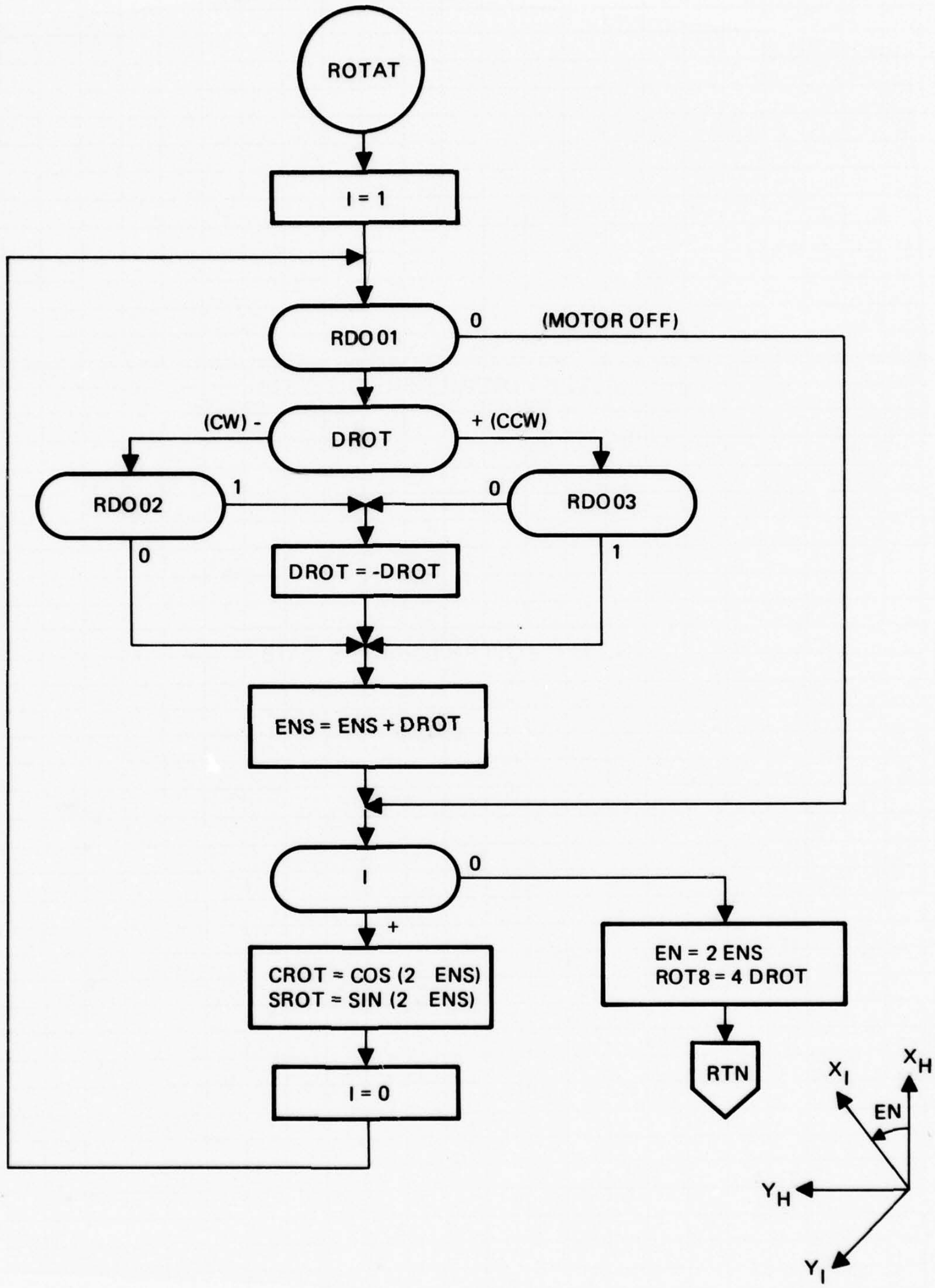
$TB_2 = -(TB_1^{-})\,SROT + (TB_2^{-})\,CROT$

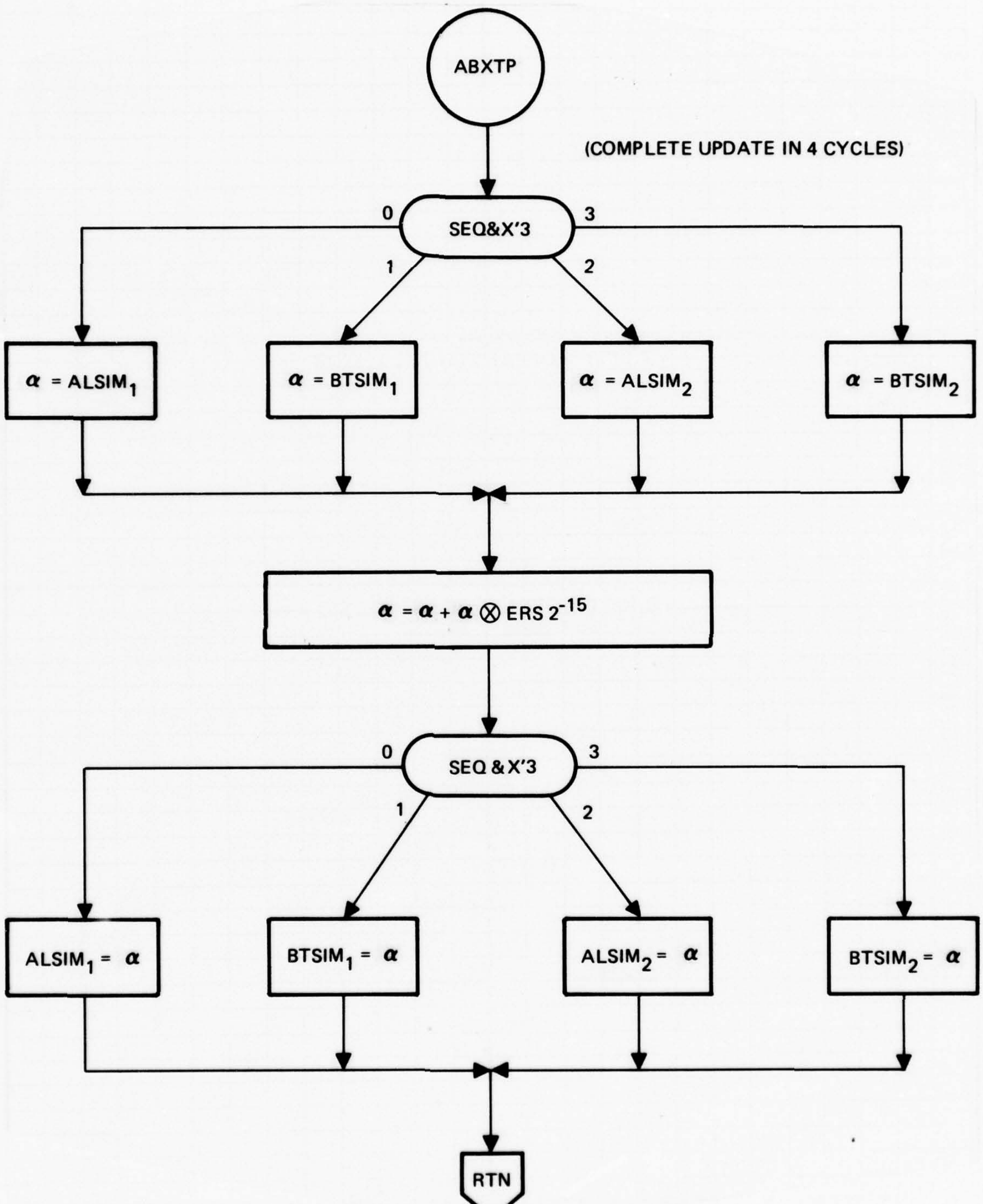
$$AL_{ij} = \sum_{m=1}^{3} CEG_{jm}\,TA_m + DCB$$

$$BT_{ij} = \sum_{m=1}^{3} CEG_{jm}\,TB_m + DCB$$

$j = 1, 2, 3$

RTN


ROTAT
I = 1
RDO 01
0
(MOTOR OFF)
DROT
(CW) -
+ (CCW)
RDO 02
1
0
RDO 03
0
1
DROT = -DROT
ENS = ENS + DROT
I
0
+
CROT = COS (2 ENS)
SROT = SIN (2 ENS)
EN = 2 ENS
ROT8 = 4 DROT
RTN
I = 0
X_I
X_H
EN
Y_H
Y_I


ABXTP
(COMPLETE UPDATE IN 4 CYCLES)
SEQ&X'3
0
1
2
3
α = ALSIM1
α = BTSIM1
α = ALSIM2
α = BTSIM2
α = α + α ⊗ ERS 2-15
SEQ & X'3
0
1
2
3
ALSIM1 = α
BTSIM1 = α
ALSIM2 = α
BTSIM2 = α
RTN

MOTR1

$AS_1 = A1S$ $BS_1 = B1S$ $SS_1 = S1S$

$AS_2 = A2S$ $BS_2 = B2S$ $SS_2 = S2S$

$AS_3 = A3S$ $BS_3 = B3S$ $SS_3 = S3S$ *

RTN

MOTR2

$AS_1 = A3S$ $BS_1 = B3S$ $SS_1 = S3S$

$AS_2 = A2S$ $BS_2 = B2S$ $SS_2 = S2S$

$AS_3 = A1S$ $BS_3 = B1S$ $SS_3 = S1S$ *

RTN

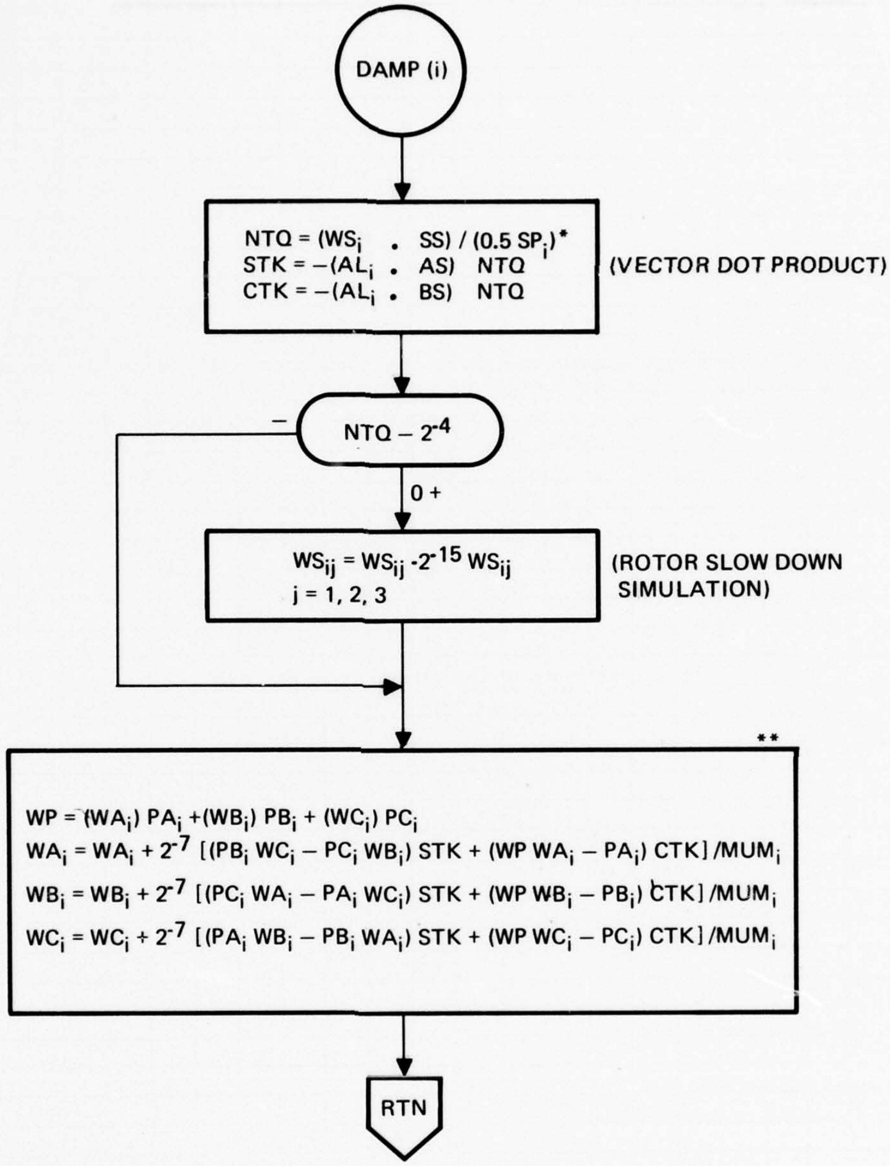
HEAT

$TROT_1 = TROT_1 + (RHEAT)\ (\theta A1S)^2$

$TROT_2 = TROT_2 + (RHEAT)\ (\theta A3S)^2$ *

RTN

* θ = ONES COMPLEMENT



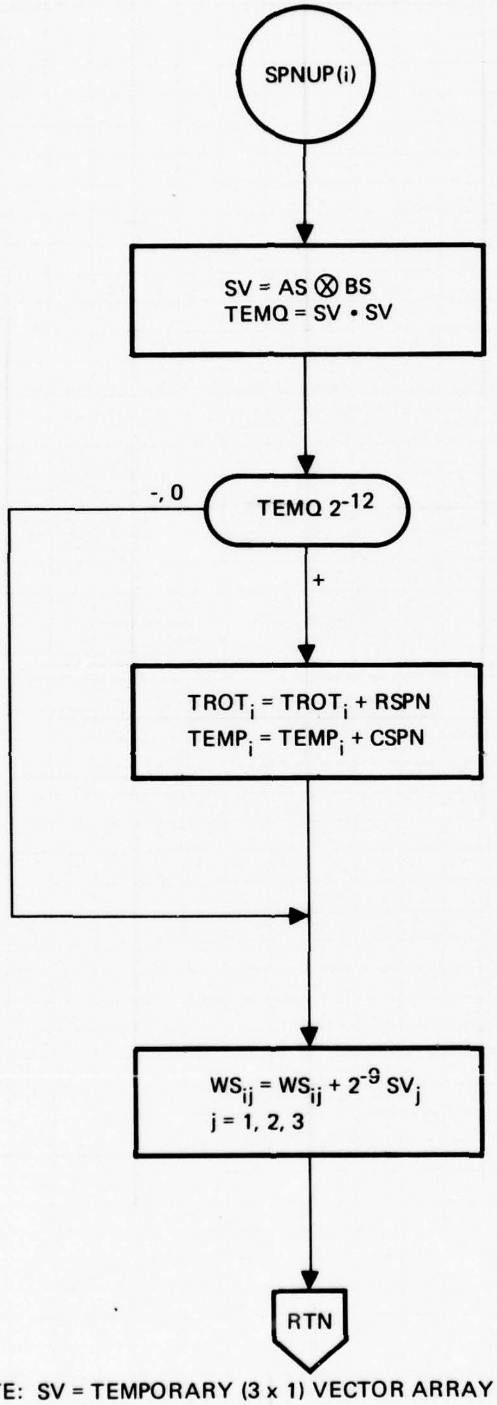
NOTE:

*SP_i HAS NO SIGN BIT ($0.5\ SP_i$ = LOGICAL RIGHT SHIFT)

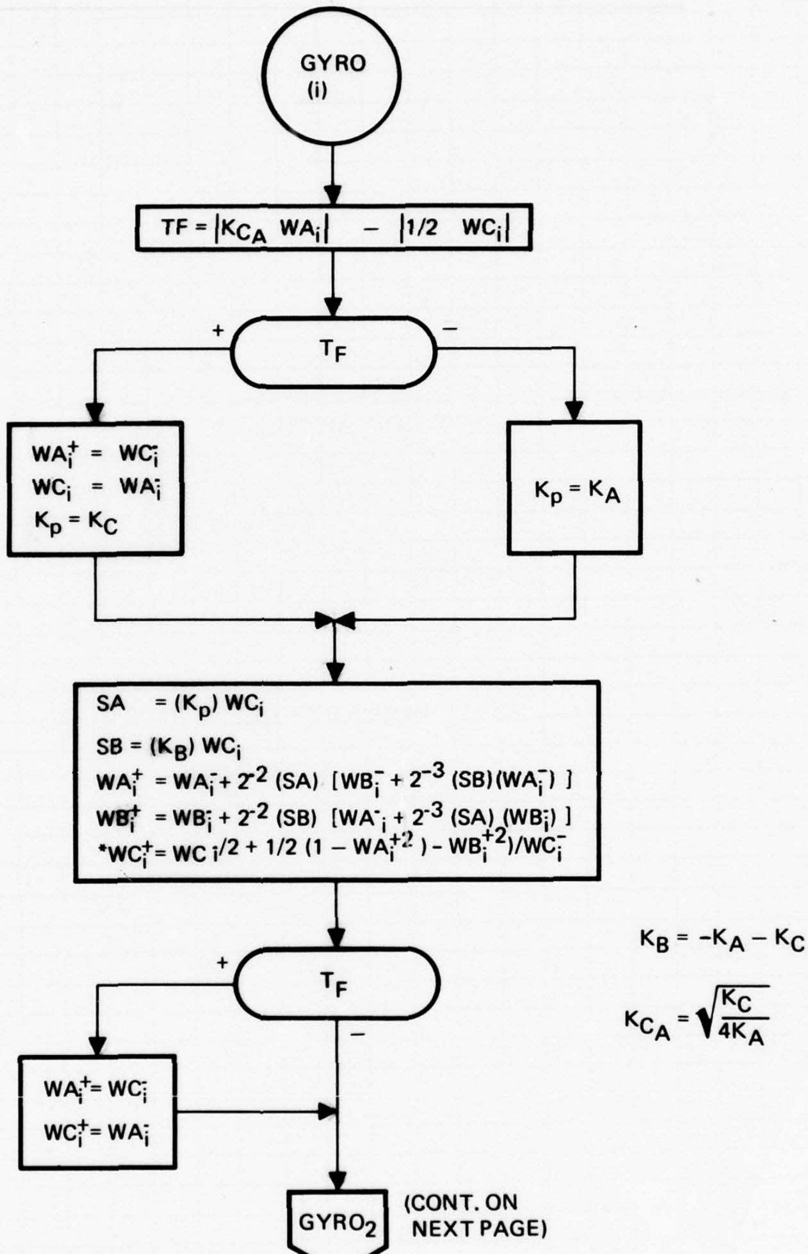
**EQUIVALENT VECTOR EQUATIONS

$$WP = W_{ABCi} \cdot P_{ABCi}$$

$$W_{ABCi} = W_{ABCi} + 2^{-6}\ [\underbrace{(P_{ABCi} \otimes W_{ABCi})}_{(VMUM_2)}\ STK + \underbrace{(WP\ W_{ABCi} - P_{ABCi})}_{(VMUM_1)}\ CTK]\ /MUM_i$$



NOTE: SV = TEMPORARY (3 x 1) VECTOR ARRAY (SV_j, j = 1, 2, 3)



*NOTE: FIRST ORDER APPROXIMATION OF

$$WC_i^+ = [1 - WA_i^2 - WB_i^2]^{1/2}\frac{WC_i^-}{|WC_i|}$$

$GYRO_2$

$$WP = WA_i\, PA_i + WB_i\, PB_i + WC_i\, PC_i$$

$$MUM_i = 7/8\,(1 - WP^2)^{1/2}$$

$$TEM_K = \sum_{n=1}^{3} CEG_{nK}\, WS_{in}$$

$$ALSIM_i = \begin{bmatrix} -TEM_2\, KS/S \\ TEM_1\, KS/S \\ 0 \end{bmatrix}$$

$$K = 1, 2, 3$$

$$S = (TEM_1^2 + TEM_2^2)^{1/2}$$

$$TSP = (S^2 + TEM_3^2)^{1/2}$$

$$SP_i = 2\,TSP$$

$$BTSIM_i = \begin{bmatrix} -ALSIM_{i2}\, TEM_3/TSP \\ ALSIM_{i1}\, TEM_3/TSP \\ (S)\,(KS)/TSP \end{bmatrix}$$

RTN

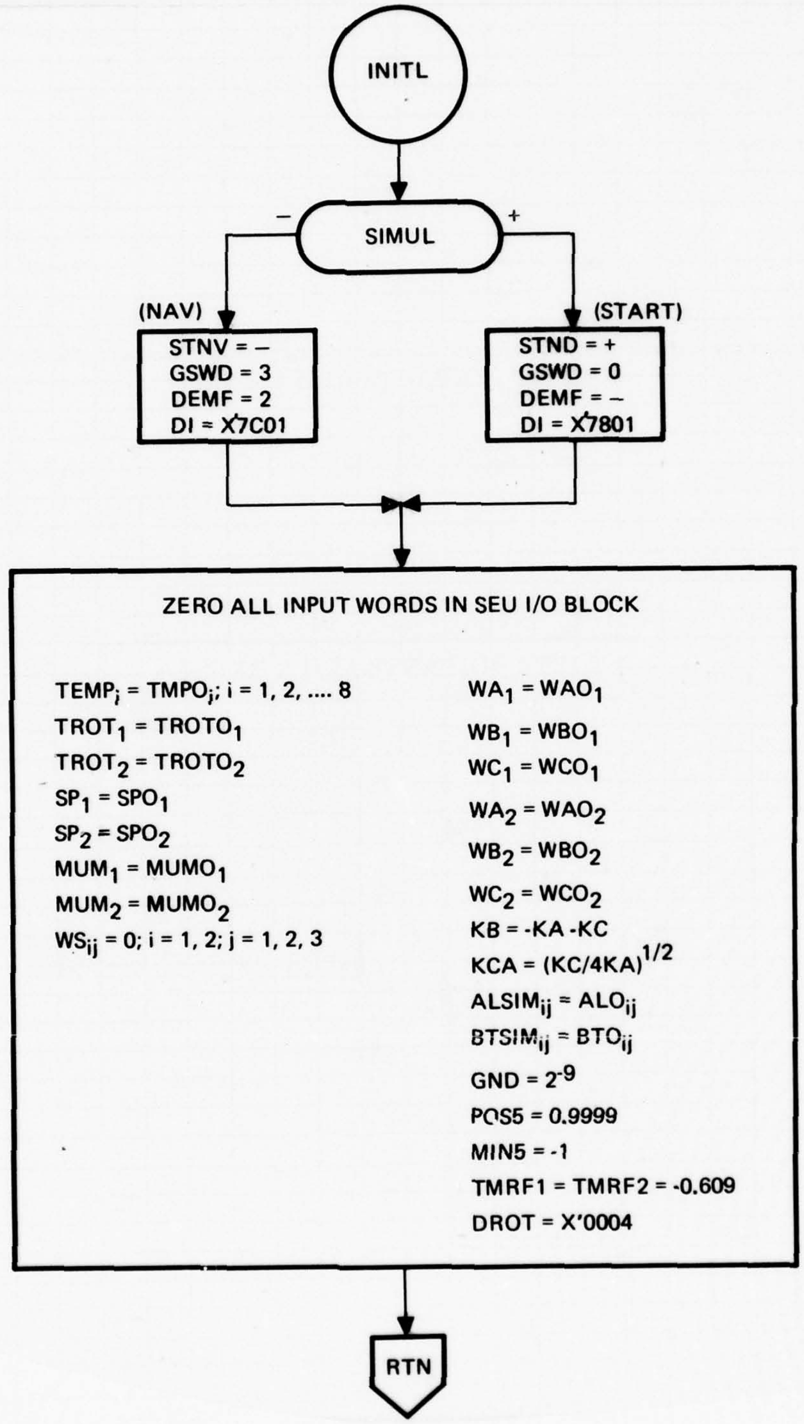

INITL
SIMUL
–
+
(NAV)
STNV = –
GSWD = 3
DEMF = 2
DI = X'7C01
(START)
STND = +
GSWD = 0
DEMF = –
DI = X'7801
ZERO ALL INPUT WORDS IN SEU I/O BLOCK
$TEMP_i = TMPO_i$; i = 1, 2, ... 8
$TROT_1 = TROTO_1$
$TROT_2 = TROTO_2$
$SP_1 = SPO_1$
$SP_2 = SPO_2$
$MUM_1 = MUMO_1$
$MUM_2 = MUMO_2$
$WS_{ij} = 0$; i = 1, 2; j = 1, 2, 3
$WA_1 = WAO_1$
$WB_1 = WBO_1$
$WC_1 = WCO_1$
$WA_2 = WAO_2$
$WB_2 = WBO_2$
$WC_2 = WCO_2$
KB = -KA -KC
$KCA = (KC/4KA)^{1/2}$
$ALSIM_{ij} = ALO_{ij}$
$BTSIM_{ij} = BTO_{ij}$
$GND = 2^{-9}$
POS5 = 0.9999
MIN5 = -1
TMRF1 = TMRF2 = -0.609
DROT = X'0004
RTN

TABLE L-1. SIMULATOR PROGRAM CONSTANTS

Symbol	Definition	Value	Max Value	Scaled Value
$GRAV_i$	Gravity + Accelerometer Bias (K_v = 0.02 fps/pulse) (1 g = 25.135 pulse)	287.365 pulse	2^{11} pulse	0.140314941
CG_1	Charge on the Rotor	2^{-7}	1	2^{-7}
CG_2		2^{-7}	1	2^{-7}
PEO_1	Accelerometer Bias + Shim, XEMA	312.5 + 0.14623	2^{11} pulse	0.15265929
PEO_2	Accelerometer Bias + Shim, YEMA	312.5 + 0.43867	2^{11} pulse	0.15280208
TXPS	Case Coefficient of Expansion	0.5578 μ in./°F	(167.9 μ in./521°F)^2	0.86544
KDM1	Frequency to Phase Conversion	1/64 sec	2^7/2604.16 Hz	0.3178906
KDM2	Demod Filter Cutoff Freq	(32 Hz)^2	2^{-7} (2604.16 Hz)^2	0.0193274
ERS_i	Earth Rate – (Body Coordinates)	-8.832456°/hr	2^{-11} rad/sec	-0.0876973
i = 1, 2, 3		-8.832456°/hr	2^{-11} rad/sec	-0.0876973
		8.379093°/hr	2^{-11} rad/sec	0.0831959
RHEAT	Rotor Heating – Z Heat Mode	1 μ in./sec	671.7 μ in./(1/64 sec)	2.32 x 10^{-5}
RSPN	Rotor Heating – Spin Mode	2^{-8} μ in.	167.9 μ in.	3.1 x 10^{-5}
CSPN	Case Heating – Spin Mode	0	312.5°F	0
K_A	Polhode Parameter [(B – C)/A] 2^{-6} sec (T_A = 1 sec)	4.7794\-6 sec	$2^{-2}/(2\pi)$ (2460 Hz) 1.617\-5	0.295498
K_C	Polhode Parameter [(A – B)/C] 2^{-6} sec	4.30155\-6 sec	$2^{-2}/(2\pi)$ (2640 Hz)	0.28095
KS	Maximum MUM Magnitude	0.875	1	0.875
DCB	Demod DC Bias	2^{-10}	1	2^{-10}
PA_1, PA_2	A Axis Pedulosity Gyros 1, 2	0.02	1	0.02
PB_1, PB_2	B Axis Pedulosity Gyros, 1, 2	-0.05	1	-0.05
PC_1, PC_2	C Axis Pedulosity Gyros 1, 2	-0.993	1	-0.993

TABLE L-1. (Cont)

Symbol	Definition	Value	Max Value	Scaled Value
DROT	Azimuth Rotation	$(3^0/64)$	360 deg	0.00013
SMCOF	SMC Offset	2^{-4}	1	2^{-4}
$TROTO_1$	Initial $TROT_i$	-139 μ in.	167.9 μ in.	-0.828
$TROTO_2$		-139 μ in.	167.9 μ in.	-0.828
SPO_1	Initial SP_i (No Sign Bit)	2457 Hz	1302.08 Hz	1.88699
SPO_2		2460 Hz	1302.08 Hz	1.88928
$MUMO_1$	Initial MUM_i	0.875	1	0.875
$MUMO_2$		0.875	1	0.875
WAO_1	Initial WA_1, WB_1, WC_1	0.98481	1	0.98481
WBO_1		0	1	0
WCO_1		0.17365	1	0.17365
WAO_2	Initial WA_2, WB_2, WC_2	0.17365	1	0.17365
WBO_2		0	1	0
WCO_2		0.98481	1	0.98481
ALO_{11}	Initial ALSIM – Gyro 1	0.90	1	0.9
ALO_{12}		0	1	0
ALO_{13}		0	1	0
BTO_{11}	Initial BTSIM – Gyro 1	0	1	0
BTO_{12}		0.9	1	0.9
BTO_{13}		0	1	0
ALO_{21}	Initial ALSIM – Gyro 2	0	1	0
ALO_{22}		0.9	1	0.9
ALO_{23}		0	1	0
BTO_{21}	Initial BTSIM – Gyro 2	0	1	0
BTO_{22}		0	1	0
BTO_{23}		0.9	1	0.9
CEG_{11}	EMA to Gyro Frame Transformation	0.75	1	0.75
CEG_{12}		-0.25	1	-0.25
CEG_{13}		0.6123724	1	0.6123724
CEG_{21}		-0.25	1	-0.25
CEG_{22}		0.75	1	0.75

TABLE L-1. (Concluded)

Symbol	Definition	Value	Max Value	Scaled Value
CEG_{23}	EMA to Gyro Frame Transformation	0.6123724	1	0.6123724
CEG_{31}		-0.6123724	1	-0.6123724
CEG_{32}		-0.6123724	1	-0.6123724
CEG_{33}		0.5	1	0.5
$TMPO_1$	Initial Temperatures (Relative to Set Point Reference Temp)	-391°F	521°F	-0.75
$TMPO_2$		-391°F	521°F	-0.75
$TMPO_3$		-234°F	312.5°F	-0.75
$TMPO_4$		-234°F	312.5°F	-0.75
$TMPO_5$		-234°F	312.5°F	-0.75
$TMPO_6$		-234°F	312.5°F	-0.75
$TMPO_7$		-234°F	312.5°F	-0.75
$TMPO_8$		-234°F	312.5°F	-0.75
MAS_1	Thermal Mass	-0.00123°F	(521.°F) (2^{-16})	-0.15472
MAS_2		-0.00123°F	(521°F) (2^{-16})	-0.15472
MAS_3		-0.001325°F	(312.5°F) (2^{-16})	-0.27787
MAS_4		-0.001325°F	(312.5°F) (2^{-16})	-0.27787
MAS_5		0.000622°F	(312.5°F) (2^{-16})	0.13044
MAS_6		0.002306°F	(312.5°F) (2^{-16})	0.48360
MAS_7		0.002306°F	(312.5°F) (2^{-16})	0.48360
MAS_8		0.001325°F	(312.5°F) (2^{-16})	0.27787
FHG	Fast Heater – Gyro	0.021°F	521°F	40×10^{-6}
FHCA	Fast Heater – Charge Amp	0.21°F	312.5°F	67×10^{-6}
FHEMA	Fast Heater – EMA	0.021°F	312.5°F	67×10^{-6}
FHSE	Fast Heater – System Electronics	0.021°F	312.5°F	67×10^{-6}
TOF	Temp Control Offset	2^{-5}	1	2^{-5}
TMGN	Temp Control DC Offset Sensor Gain	-0.2	1	-0.2
SMGN	SMC DC Offset Sensor Gain	-0.5	1	-0.5

TABLE L-2. SIMULATOR PROGRAM VARIABLES

Symbol	Index i	Index j	Definition	Max Value	Word Length (Bits)
$TEMP_i$	(1, 2, ... 8)	–	Simulated Temperatures	$521^\circ F$ i = 1,2; $312.5^\circ F$ i = 3-8	32
$TROT_i$	Gyro (1, 2)	–	Rotor Temp	167.9 μ in	32
SPD	–	–	TD Frequency (Dummy Variable) (No Sign Bit)	1302.08 Hz	16
SP_i	Gyro (1, 2)	–	Rotor Speed (No Sign Bit)	1302.08 Hz	16
$ALSIM_{ij}$	Gyro (1, 2)	Axis (1, 2, 3)	Inertial α (Body Coordinates)	1	32
$BTSIM_{ij}$	Gyro (1, 2)	Axis (1, 2, 3)	Inertial β (Body Coordinates)	1	32
WS_{ij}	Gyro (1, 2)	Axis (1, 2, 3)	Spin Vector (Case Coordinates)	2604.16 Hz	32
WA_i, WB_i, WC_i	Gyro (1, 2)	–	Spin Vector (Rotor Coordinates) Normalized on Rotor Speed)	1	32
AS_i, BS_i, SS_i	Axis (1, 2, 3)	–	Spin Motor Commands Reordered into (x, y, z)	1	16
CROT	–	–	Cos of Platform Rotation Angle	–	16
SROT	–	–	Sin of Platform Rotation Angle	–	16
COSU	–	–	Cos Slip Angle	1	16
SINR	–	–	Sin Slip Angle	1	16
PE_i	EMA (1, 2, 3)	–	EMA Pulses + Residual	2^{11} pulse	32
PH_i	Gyro (1, 2)	–	Net Demod Phase Slip	$2^8 \pi$ rad	32
DELTS	–	–	Slip Frequency	2604.16 Hz	16
FQO_i	Gyro (1, 2)	–	Previous Demod Command (No Sign Bit)	1302.08 Hz	16
MUM_i	Gyro (1, 2)	–	MUM Magnitude	1	16
K_B	–	–	Polhode Parameter	1	16
KCA	–	–	Polhode Parameter	1	16

TABLE L-3. GYRO PARAMETER LIST SIMULATOR VALUES

Word	Parameter	Value	Scaled Value	Word	Parameter	Value	Scaled Value
1-24	DAL11 - DBT23	0	0	54	TCMO	130°F	0.366
				55	VROLD	4.06V	0.609
25	HZC1	2460 Hz	X'F1D0				
26	HZC2	2458 Hz	X'F1A2	56	HRSCL	0	0
27	TPNB1	1 sec	2^{-6}	57, 58	LATC	33° 51.26'	0.1886796294
28	TPNB2	1 sec	2^{-6}	59, 60	LONC	-117° 50.88'	-0.6547111111
29	THA1	-1	-1	61, 62	ALTC	235 ft	0.0018
30	THA2	-1	-1	63, 64	SMHDG	0	0
31	GP121	0.5	0.5				
32	GP122	0.5	0.5	65	KRB1C	0	0
33	PHASE	90°	0.5	66	KPB1C	0	0
				67	KHB1C	0	0
34	GD01	264μ in.	X'16B0	68	KRB3C	0	0
35	GD02	256μ in.	X'1600	69	KPB3C	0	0
36	GS01	63μ in.	X'309C	70	KHB3C	0	0
37	GS02	62.8μ in.	X'2FEC	71	ENO	0	0
				72	ROLO	0	0
38	TC01	-325.6°F	X'B000	73	PITO	0	0
39	TC02	-325.6°F	X'B000	74	PITO1	0	0
40	TSC1	-101.4°F	X'B000				
41	TSC2	-101.4°F	X'B000				
42	TSE	-101.4°F	X'B000				
43	TSS1	-101.4°F	X'B000				
44	TSS2	-101.4°F	X'B000				
45	TSS3	-101.4°F	X'B000				
46-49	Spare	–	–				
50	TMX10	159.8°F	0.27064				
51	TMX20	159.8°F	0.27064				
52	TAIRO	95°F	0.478				
53	TBATO	80°F	0.526				

TABLE L-4. PRMA - EMA LIST

Simulator Values

Word	Parameter	Value	Scaled Value
1, 2	$\nabla V1$	-312.64623p	-0.61063717
3, 4	$\nabla V2$	-312.93867p	-0.61120834
5, 6	$\nabla V3$	-312.5p	-0.61035156
7, 8	KV11		-0.48
9, 10	KV12		+0.16
11, 12	KV13		-0.391918336
13, 14	KV21		+0.16
15, 16	KV22		-0.48
17, 18	KV23		-0.391918336
19, 20	KV31		+0.391918336
21, 22	KV32		+0.391918336
23, 24	KV33		-0.32
25	CBM11		-0.3535426
26	CBM21		-0.3535426
27	CBM31		0.8659989
28	-CBM12		0.707085
29	-CBM22		-0.707085
30	-CBM32		0
31	-CBM13		0.6123537
32	-CBM23		0.6123537
33	-CBM33		0.4999847

$$\text{CEG} * 0.02\ \text{fps/p}/2^{-5}\ \text{fps/p} * \begin{pmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{pmatrix}$$

TABLE L-5. $PRMG_1$ AND $PRMG_2$ - GYRO LIST

Simulator Values

Word	Parameter	Value	Scaled Value
1-12	ΔCGM	0	0
13-80	Angle	0	0
81-119	Drift	0	0
120-126	Spare	0	0
127	SFA1	0.270	0.270
128	SFA2	0.270	0.270
129	SFA3	0.270	0.270
130	PHB1	0	0
131	PHB2	0	0
132	PHB3	0	0
133	PHA1	0	0
134	PHA2	0	0
135	PHA3	0	0
136	SFB1	0.270	0.270
137	SFB2	0.270	0.270
138	SFB3	0.270	0.270

APPENDIX M

EPM THERMAL DESIGN AND ANALYSES

As throughout the design evolution of the MICRON INS, extensive thermal analyses were performed during Phase 2B. These analyses were made at both the INU and module levels and were essential as an aid and as confirmation of the EPM thermal design. INU level analyses consisted of setting up a 140-node thermal network model of the physical INU design and exercizing the network by means of the IBM 370 computer, using the Rockwell XF0014 General Thermal Analyzer Program. These computer analyses permitted parametric studies, by varying the network parameters, to determine system thermal design characteristics and requirements such as heater sizes and locations, control set points and control loop parameters for stable operation, system thermal responses to fast reaction and over-cooling transients and steady-state coldplate temperatures as a function of cooling air and environmental conditions. The module level analyses provided detail parts operating temperatures and thermal stresses as primary input data for reliability predictions, using coldplate temperature from the INU analyses as bases.

The requirements and objectives of the MICRON EPM thermal design were the following:

1. Temperature Control. Regulate inertial instrument and critical electronics temperature within limits prescribed by performance considerations within the specified ranges of cooling air and environmental conditions.

2. Electronics Cooling. Provide efficient cooling of non-controlled electronics to minimize temperature and maximize reliability throughout specified ranges of cooling air and environmental conditions.

3. Transient Conditions. Provide capability to meet specified thermal transient conditions, including cold-start fast reaction and overcooling.

The EPM thermal design, which evolved from extensive thermal analyses and from XN-77 and N57A experience, is depicted byFigures M-1 and M-2. The following design features were incorporated:

1. Maximum isolation of temperature controlled and non-controlled zones. The IAU and SEU thermally controlled regions are identified in Figure M-1.

2. Integral chassis coldplate cooling of MHU electronics with wedge-lock module retention. Isolated, externally finned IAU. No contact of cooling air contaminated with moisture and debris with circuit components. (Figure M-2).

3. External copper heat rail thermal shunts on electronic modules for efficient, predictable thermal performance.

4. Eight (8) proportional temperature control channels which use resistive heating and the DPU as the controller.

5. Four (4) fast reaction heater circuits which are controlled by DPU issued discretes via relays.

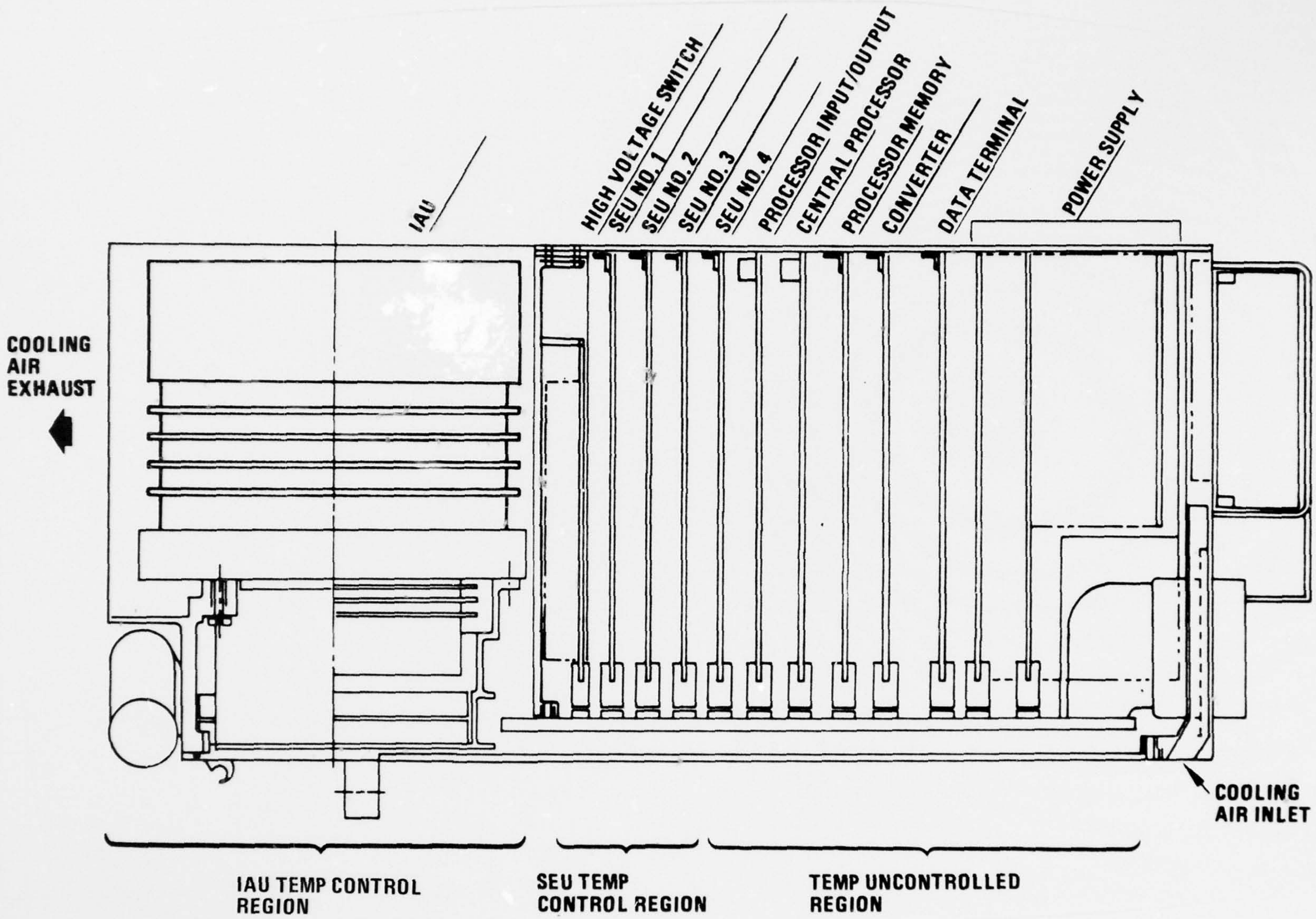


Figure M-1. INU Thermal Design Configuration

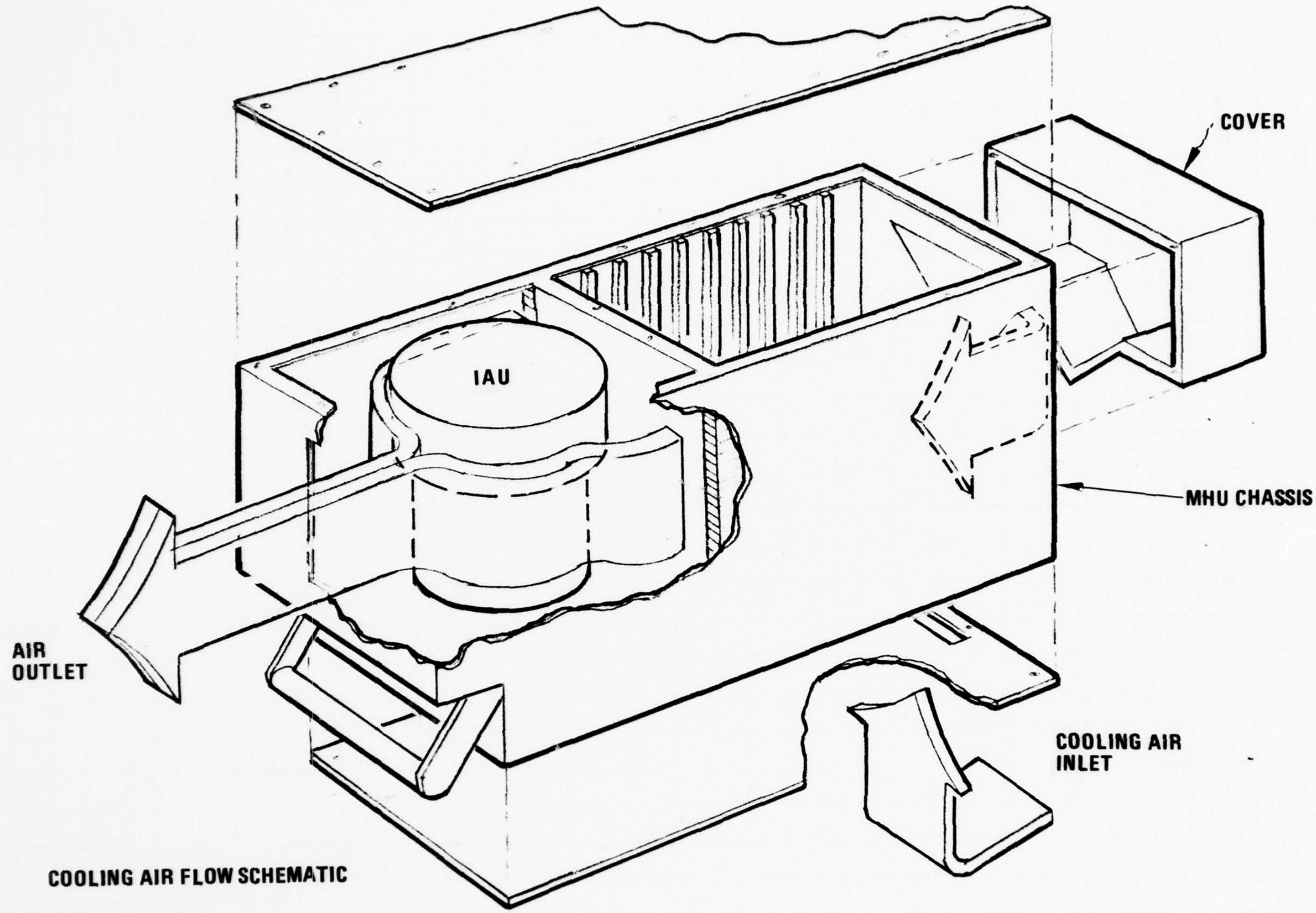


Figure M-2. INU Cooling Air Flow Schematic

The design heat load, excluding heaters, is given by Table M-1. Approximately 300 watts are dissipated under normal operation. Tables M-2 and M-3 list EPM temperature control heater and fast reaction heater characteristics, respectively. Maximum control heater power, i.e., all control heaters fully on as during startup, is 190 w. Nominal heater power at nominal cooling air flow conditions is 50-60 watts, as shown by Figure M-3. The total fast reaction heater power of 1770 watts provide warm up at the $80^{\circ}F$/min heating rate, requiring only 2 minutes of heating from $0^{\circ}F$ start.

The EPM thermal design was developed and verified by extensive thermal analyses at both the INU and module levels. The INU level analyses consisted of synthesizing a thermal network (model) of the INU physical-thermal design and exercising the network by means of the IBM 370 computer, using the Rockwell XF0014 General Thermal Analyzer Program. These computer analyses permitted parametric studies, by varying the network parameters, to determine optimal system thermal design requirements and characteristics such as heater sizes and locations, sensor locations, control set points, control loop parameters for stable operation, system thermal responses to fast reaction and overcooling transients, and steady-state coldplate temperatures as a function of cooling air and environmental conditions.

Figure M-4 shows the thermal network of one-half of the INU. The relationship of the rotating IAU nodes to the IAU physical design is detailed in Figure M-5. Figures M-6 and M-7 are computer generated CRT plots showing thermal response of elements of the IAU to a typical fast reaction transient condition.

Module level thermal analyses were performed for each module type. These analyses consisted of hand calculations of component temperature rises relative to a reference coldplate temperature. The reference coldplate temperatures were determined by the computerized INU level analyses.

An example of a module level analysis is shown by Figure M-8 for the SEU No. 4 Module. (This example was chosen since it was the simplest module but still illustrated the procedure used.) A thermal balance algebraic expression was generated for each "rail" such as the rail for U1, Q7 and Q6, and temperature rises were calculated for each electronic part for module lock thermal contact, conduction along the copper rail, contact from rail to part case, and part case to junction, if applicable. Each hybrid package was treated as a single heat source. Additionally, the junction temperatures of the most highly stressed semiconductors of each hybrid were calculated. Table M-4 shows the thermal results of the SEU No. 4 analysis example.

TABLE M-1. MICRON EPM DESIGN HEAT LOAD

ESTIMATED HEAT LOAD (EXCLUDING HEATERS)			
HEAT SOURCE	HEAT MODE	SPIN/DAMP MODE	NORMAL OP
ELECTRONICS			
PSU NO. 1	52.0 W	52.0 W	52.0 W
PSU NO. 2	60.0	60.0	60.0
PSU NO. 3	15.0	15.0	15.0
DTU	25.0	25.0	25.0
CONVERTER	65.0	65.0	65.0
DPU – MEMORY	10.9	10.9	10.9
DPU – CPU	14.9	14.9	14.9
DPU – I/O	8.9	8.9	8.9
SEU NO. 4	4.7	4.7	4.7
SEU NO. 3	5.7	5.7	5.7
SEU NO. 2	2.7	2.7	2.7
SEU NO. 1	2.7	2.7	2.7
HV SWITCH, XFMR & MISC MHU	10.0	10.0	7.0
SUBTOTAL	277.5 W	277.5 W	274.5 W
IAU			
CHARGE AMP ASSY (2)	8.7 W	8.7 W	8.7 W
EMA (3)	4.0	4.0	4.0
ESG (2) & HVPS	80.8	18.4	4.8
SMPA	118.4	100.4	0.5
MOTOR, ENCODER, ETC.	10.0	10.0	10.0
SUBTOTAL	221.9 W	141.5 W	28.0 W
TOTAL	499.4 W	419.0 W	302.5 W

TABLE M-2. MICRON EPM TEMPERATURE CONTROL REQUIREMENTS

EPM TEMPERATURE CONTROL REQUIREMENTS

TEMPERATURE CONTROL HEATER LOCATIONS	NOMINAL HEATER POWER	MAXIMUM HEATER POWER	NOMINAL SET POINT	REGULATION
1. ESG NO. 1	5 W	10 W	71°C	0.25°C
2. ESG NO. 2	5	10	71°C	0.25°C
3. EMA BLK/ESG MT	10	50 *	71°C	0.25°C
4. CHARGE AMP NO. 1	5	15	71°C	0.8°C
5. CHARGE AMP NO. 2	5	15	71°C	0.8°C
6. SEU NO. 1	10	30	63°C	0.9°C
7. SEU NO. 2	10	30	63°C	0.9°C
8. SEU NO. 3	10	30	63°C	1.0°C
TOTAL	60 W	190 W		

* CONTROLLED BY EMA BLOCK SENSOR

30 W ON EMA BLOCK

20 W ON MOUNT

TABLE M-3. MICRON EPM FAST REACTION HEATER REQUIREMENTS

FAST REACTION HEATER REQUIREMENTS			
FR HEATER LOCATION		REQUIRED HEATER SIZE	RELAY NO.**
IAU			
1. ESG NO. 1		*60 W	K5
2. ESG NO. 2		*60	K5
3. EMA NO. 1		*40	K3
4. EMA NO. 2		*40	K3
5. EMA NO. 3		*40	K3
6. ESG MOUNT		280	K5
7. EMA BLK		220	K3
8. CHARGE AMP HOUSING		200	K4
9. CHARGE AMP NO. 1		70	K4
10. CHARGE AMP NO. 2		70	K4
	SUBTOTAL	1080 W	
SEU			
1. SEU NO. 1		230 W	K2
2. SEU NO. 2		230	K2
3. SEU NO. 3		230	K2
	SUBTOTAL	690 W	
	TOTAL	***1770 W	

* EXISTING PART OF INSTRUMENT

** K5 OPENS WHEN AVERAGE TEMPERATURE OF ESG 1 AND ESG 2 EXCEEDS 145°F
K3 OPENS WHEN EMA BLOCK TEMPERATURE EXCEEDS 159°F
K4 OPENS WHEN AVERAGE TEMPERATURE OF CA 1 AND CA 2 EXCEEDS 159°F
K2 OPENS WHEN AVERAGE TEMPERATURE OF SEU 1, SEU 2, AND SEU 3 EXCEEDS 143°F

*** INU FAST REACTION HEATER POWER FOR 80°F/MIN HEATING RATE.
FOR 0°F START TEMPERATURE, HEATER POWER REQUIRED FOR 2 MINUTES ONLY.

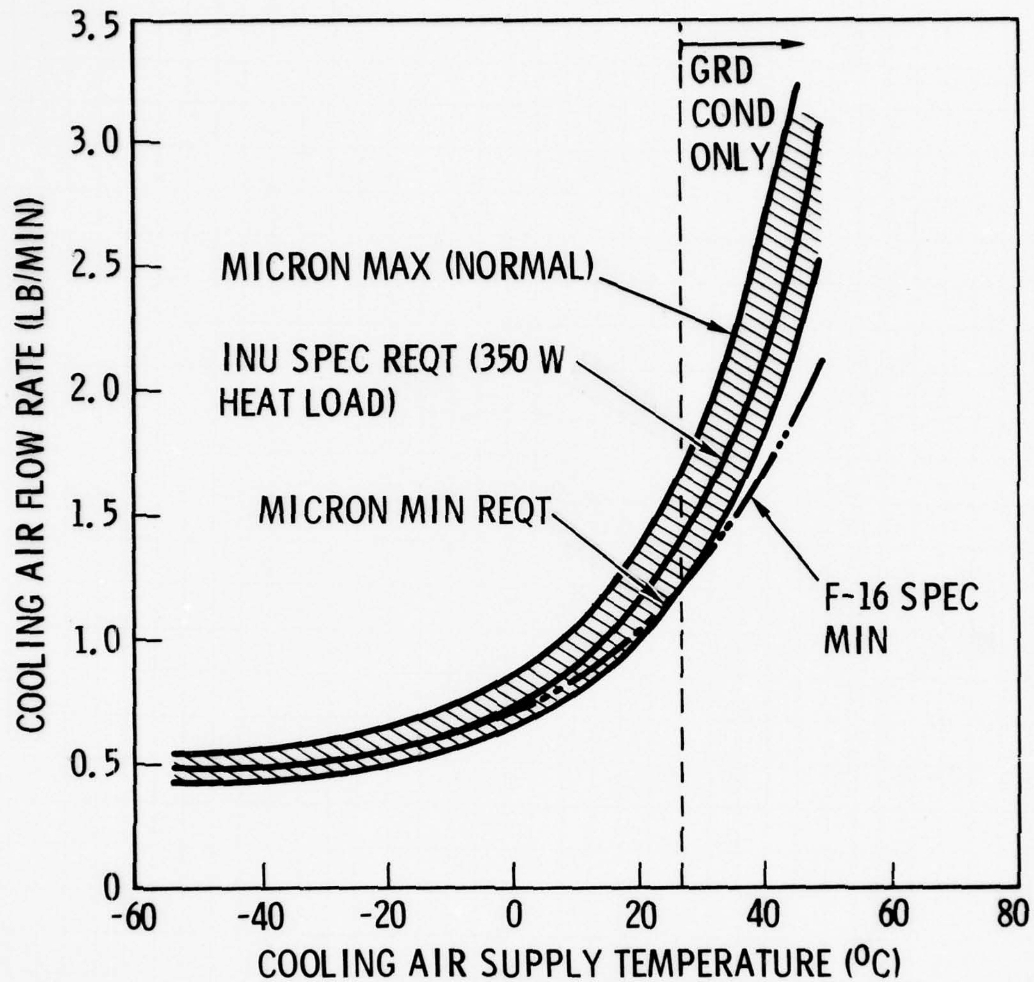


Figure M-3. MICRON EPM Cooling Air Requirements

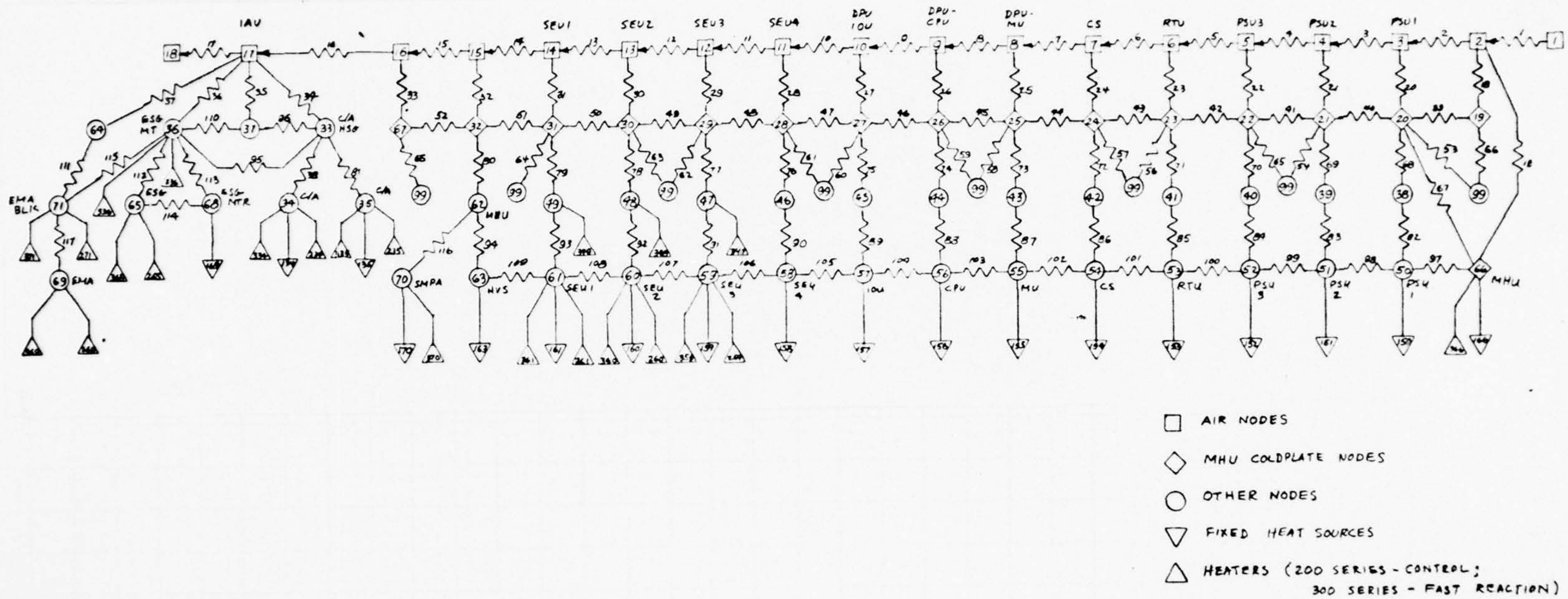


Figure M-4. MICRON EPM INU Thermal Network

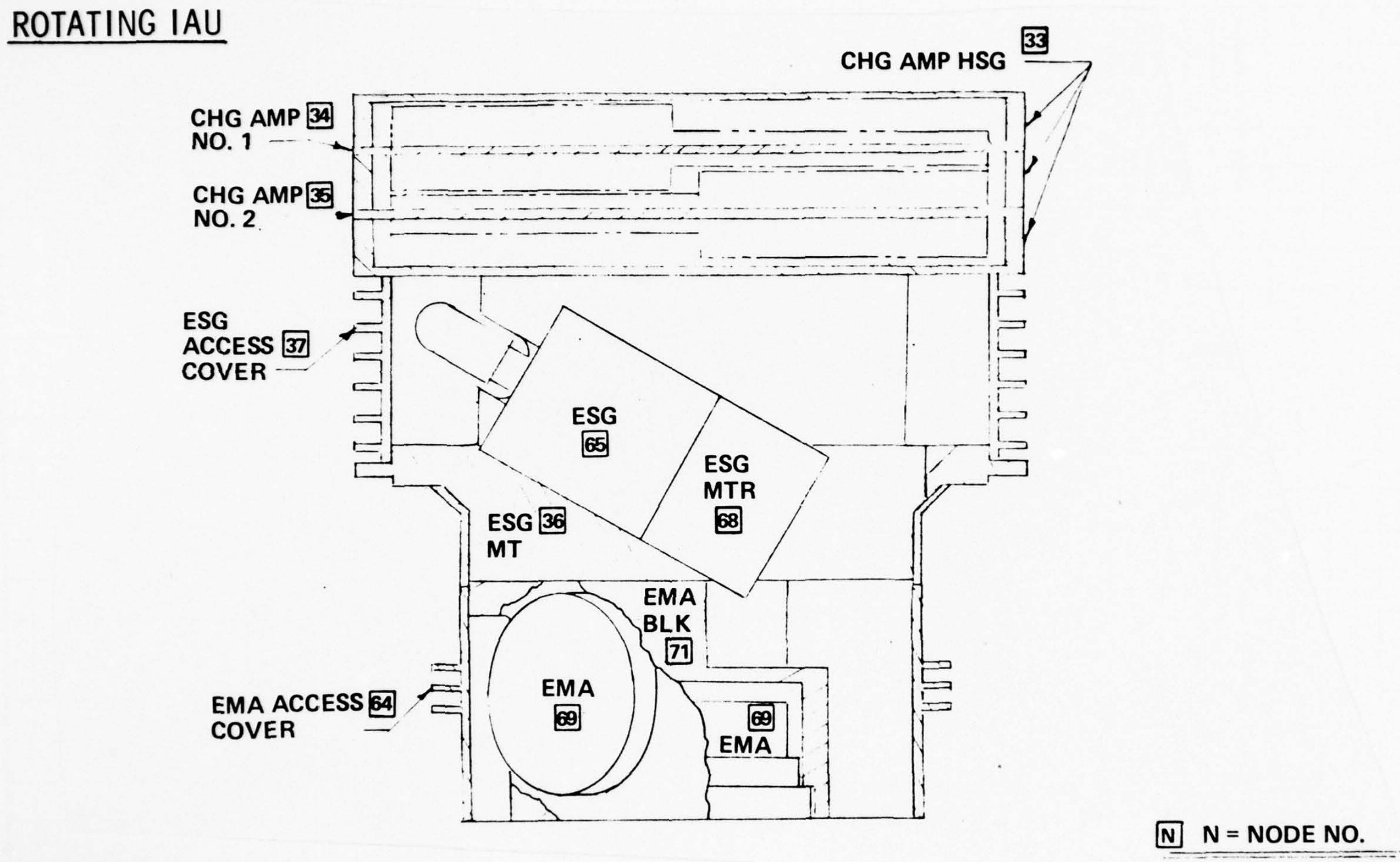


Figure M-5. EPM IAU Thermal Design

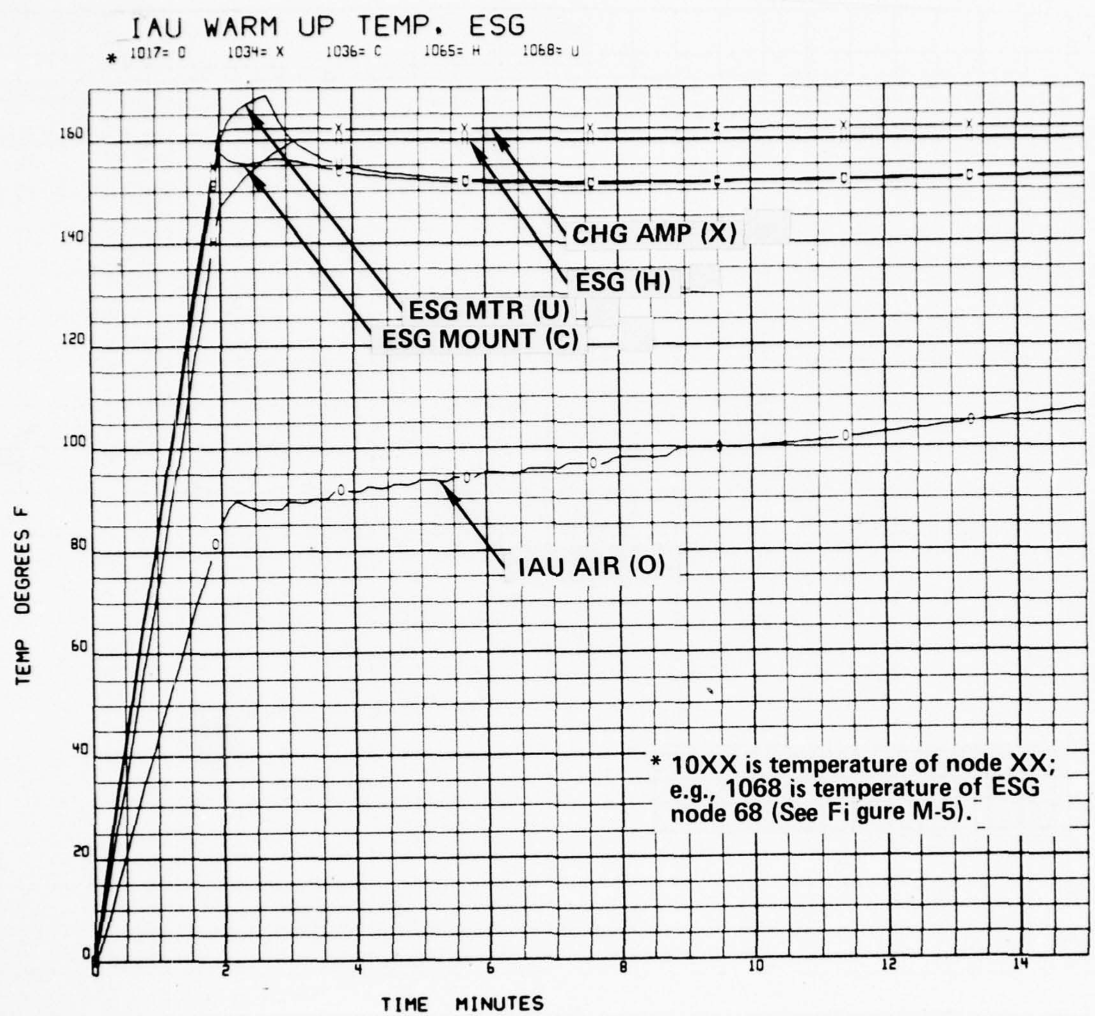


Figure M-6. ESG Fast Reaction Thermal Response

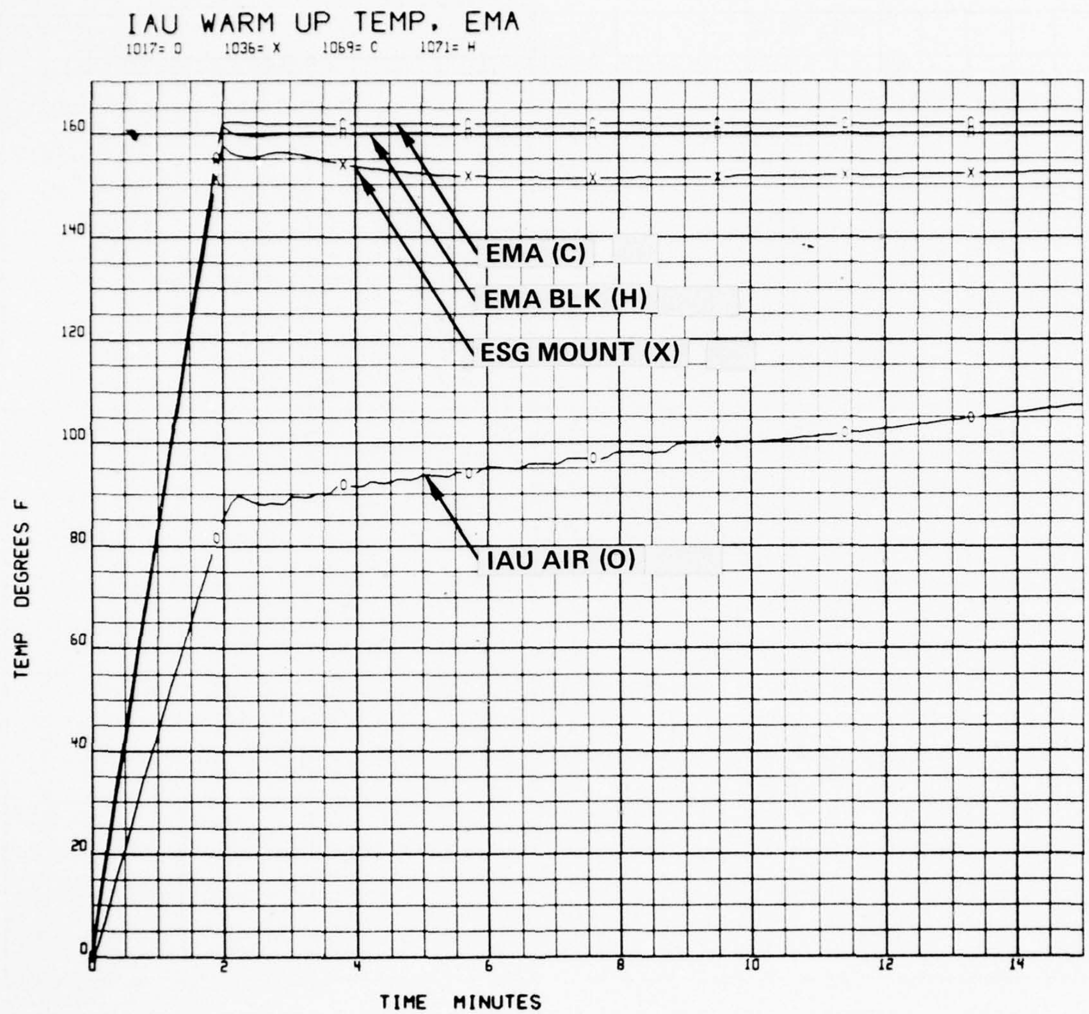


Figure M-7. EMA Fast Reaction Thermal Response

MODULE THERMAL ANALYSIS - SEU NO. 4 EXAMPLE

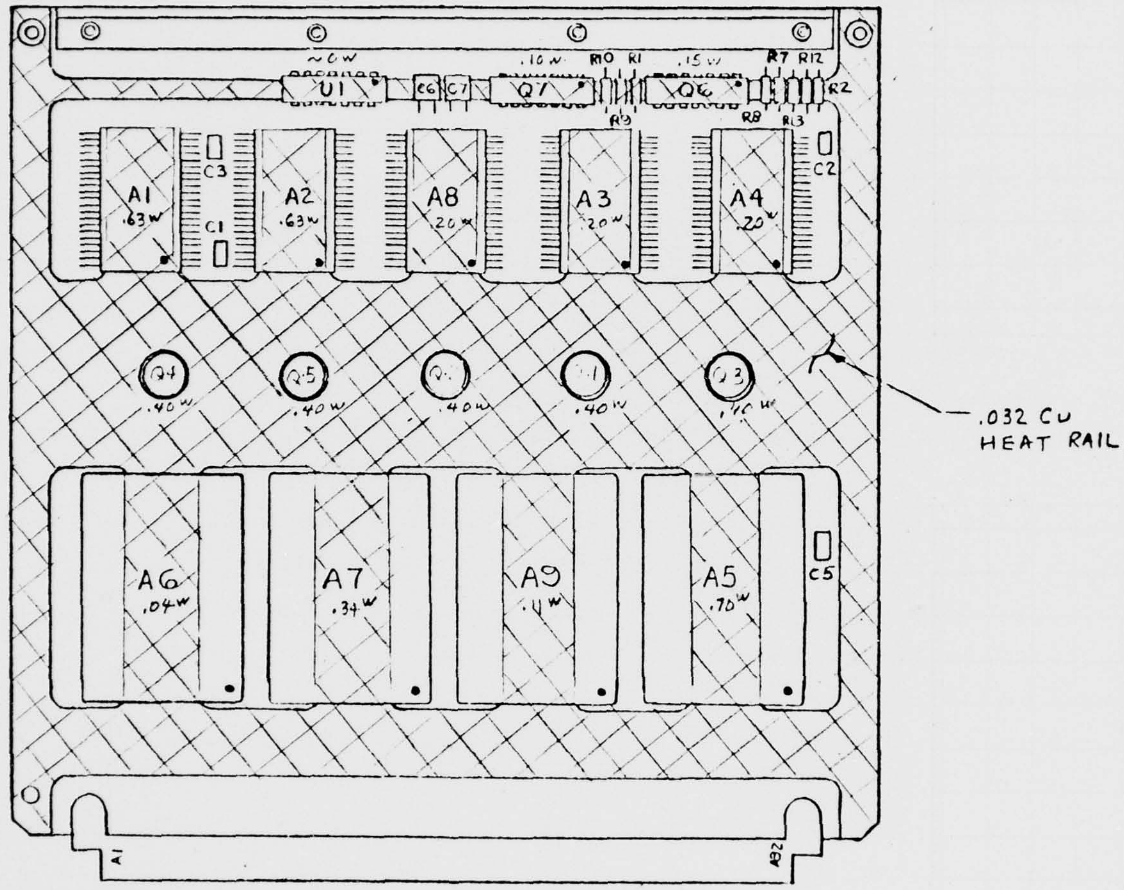


Figure M-8. Module Thermal Analysis - SEU No. 4 Example

TABLE M-4. MODULE THERMAL ANALYSIS RESULTS, SEU NO. 4 EXAMPLE

COMPONENT REF SYMBOL	P_D-HEAT DISS (WATTS)	ΔT_{WEDGE} (°C)	ΔT_{RAIL} (°C)	ΔT_{c-r} (°C)	ΔT_{j-c} (°C)	T_{CASE} (°C)	T_{JUNC} (°C)	RATING T_j	RATING P_D	STRESS T_j	STRESS P_D
U1 (3)	~.002	0.4	4.4	~0	~0	53.8	53.8	150	0.5	.230	.004
Q7 (7)	<.10	1.0	7.4	0.3	2.3	57.7	60.0	200	1.9	.200	.053
Q6 (7)	<.15	1.0	6.3	0.4	3.5	56.7	60.2	200	1.9	.201	.079
A1 (4)	.63	2.0	7.0	0.8	1.3	58.8	60.1	175		.234	
A2 (4)	.63	2.0	10.5	0.8	1.3	62.3	63.6	175		.257	
A8 (6)	.20	2.0	8.9	0.3	0.4	60.2	60.6	175		.237	
A3 (5)	.20	2.0	7.9	0.3	0.4	59.2	59.6	175		.231	
A4 (5)	.20	2.0	5.1	0.3	0.4	56.4	56.8	175		.212	
Q4 (2)	.40	2.0	4.2	2.5	8.0	57.7	65.7	200	8.75	.232	.05
Q5 (1)	.40	2.0	7.2	2.5	8.0	60.7	68.7	200	8.75	.250	.05
Q2 (2)	.40	2.0	7.8	2.5	8.0	61.3	69.3	200	8.75	.253	.05
Q1 (1)	.40	2.0	6.9	2.5	8.0	60.4	68.4	200	8.75	.248	.05
Q3 (1)	.40	2.0	4.6	2.5	8.0	58.1	66.1	200	8.75	.235	.05
A6 (10)	.04	2.0	4.3	0.1		55.4					
(RM 4136)					1.9(12)		57.3	175		.215	
A7 (11)	.34	2.0	8.5	0.3		59.8					
(RM 4136)					1.9(12)		61.7	175		.245	
A9 (8)	.11	2.0	7.5	0.1		58.6					
A5 (9)	.70	2.0	6.5	0.7		58.2					

(1) U2T151 UNITRODE DARLINGTON (2) U2T101 DARLINGTON (3) SN 54090J (4) DAC MOS (5) Q REF MOS
(6) METG MOS (7) MHQ 2222 XSTR (8) CAL STORE NO. 1 (9) CAL STORAGE NO. 2 (10) SM CONTROLLER – T_j FOR RM 4136
(11) TEMP CONTROLLER – T_j FOR RM 4136 (12) 76-552-EDA-22 JANDRASI COLD PLATE REF TEMP = 49°C

APPENDIX N. NAVIGATION PERFORMANCE DATA

This appendix contains EPM individual navigation plots as well as ensemble CEP and velocity error curves. Figures N-1 through N-6 show summary and ensemble plots while the individual navigation performance plots are given in Figures N-7 through N-34.

EPM 1 navigation position and velocity plots are contained in Figures N-7 through N-23. Plots are provided for all navigation runs made through 25 February 1977 with the IAU rotating. (Some navigation runs were made in December 1976 without the IAU rotating.) The two demonstration navigation runs are No. 1230761825 and 1230762239 shown in Figures N-11 and N-12, respectively. Position and velocity error summaries are plotted in Figures N-1 and N-2 summarizing the EPM 1 navigation performance.

Navigation plots are provided (Figures N-24 through N-34) for EPM 2 rotating IAU testing through February 1977. (This testing was not performed with contract funding. The data has been included in this report to provide a broader statistical base for evaluation of the navigation performance of the EPM design.) One navigation run made on 28 January 1977 has been excluded since it was made with a defective SEU 1 module. Position and velocity error summaries are plotted in Figures N-3 and N-4 for the EPM 2 navigation performance.

Figures N-5 and N-6 contain the summary plots for the ensemble of EPM 1 and EPM 2 navigation runs.

AD-A048 001 ROCKWELL INTERNATIONAL ANAHEIM CALIF AUTONETICS GROUP F/G 17/7
MICRO NAVIGATOR (MICRON) PHASE 2B. VOLUME II - APPENDICES.(U)
AUG 77 J M MILLER, A P ANDREWS, T F BRASHER F33615-75-C-1301
UNCLASSIFIED C75-787/201-VOL-2 AFAL-TR-77-138-VOL-2 NL

4 OF 4
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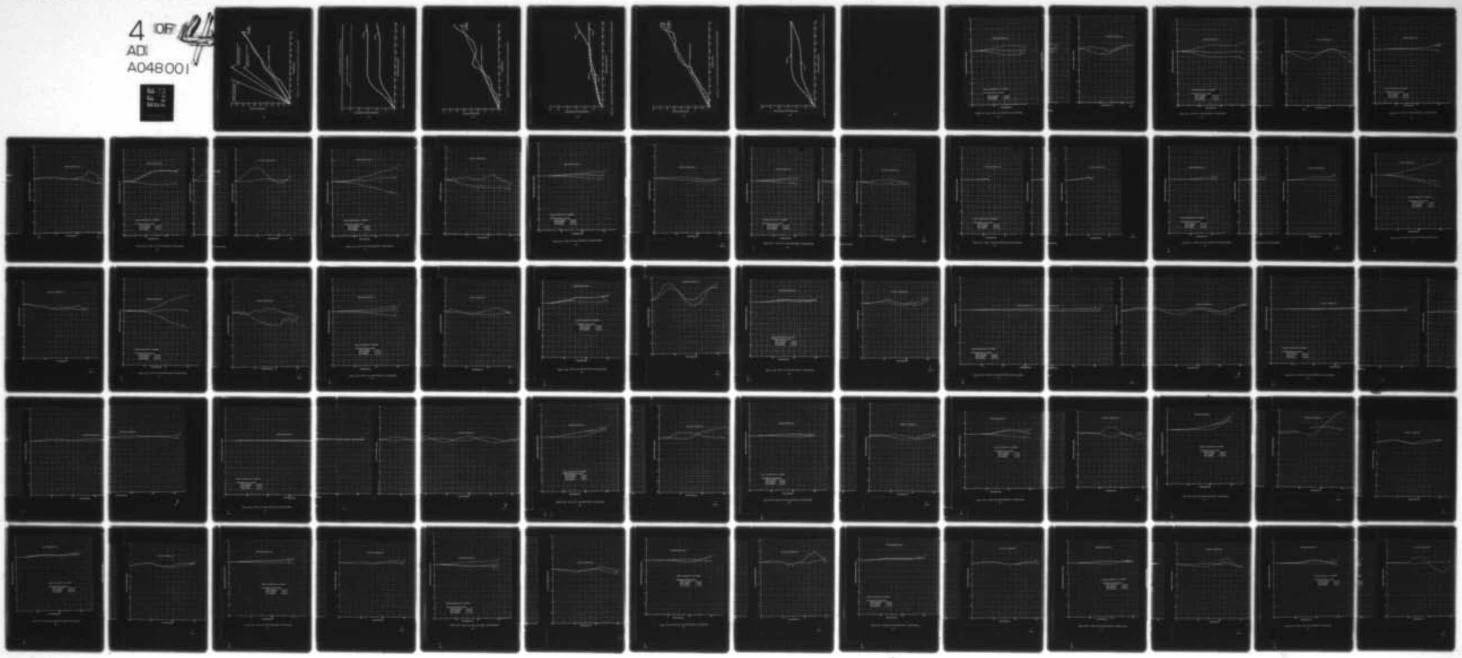
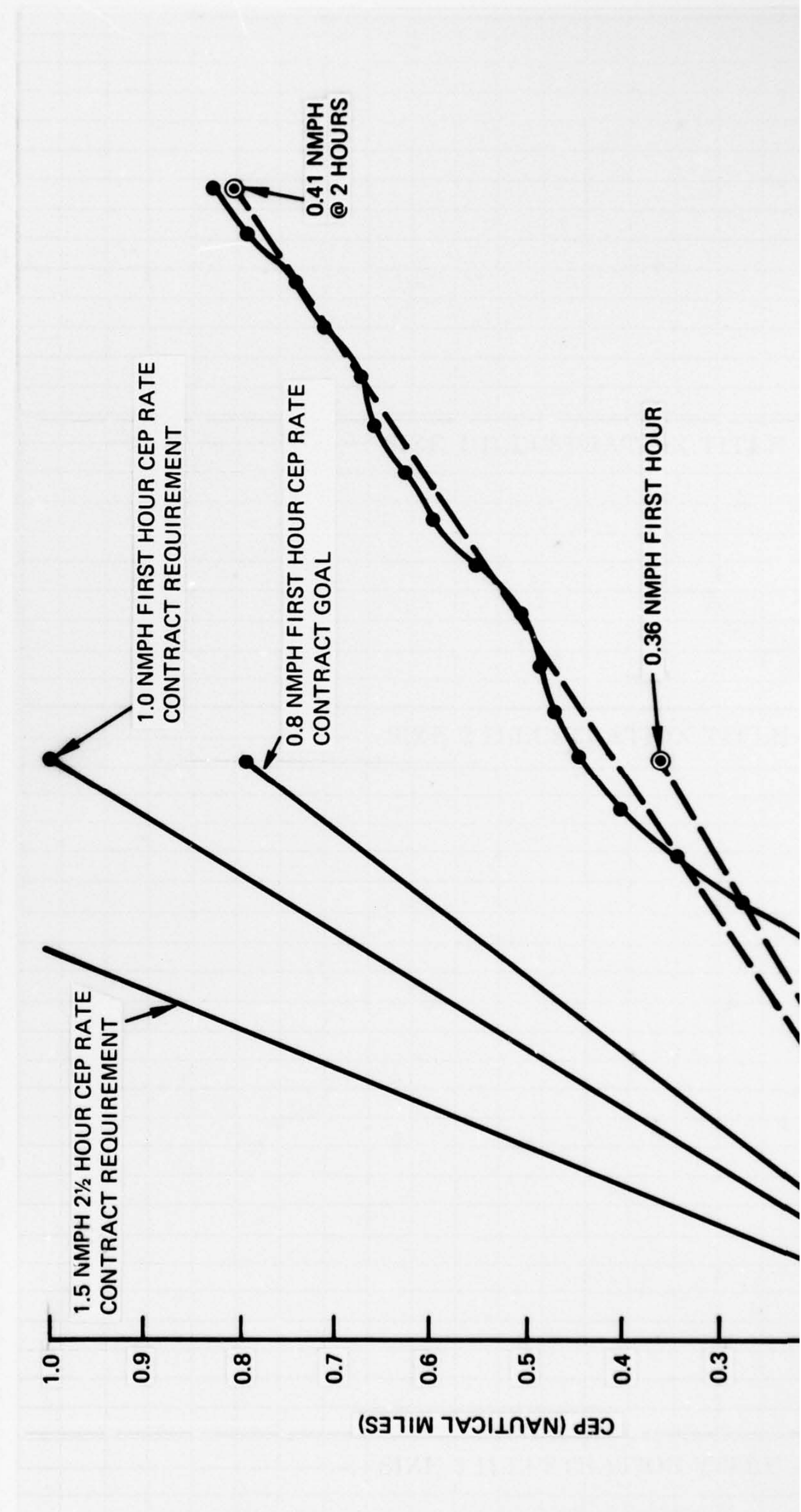


END
DATE
FILMED
1-78
DDC


CEP (NAUTICAL MILES)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
1.5 NMPH 2½ HOUR CEP RATE CONTRACT REQUIREMENT
1.0 NMPH FIRST HOUR CEP RATE CONTRACT REQUIREMENT
0.8 NMPH FIRST HOUR CEP RATE CONTRACT GOAL
0.41 NMPH @ 2 HOURS
0.36 NMPH FIRST HOUR

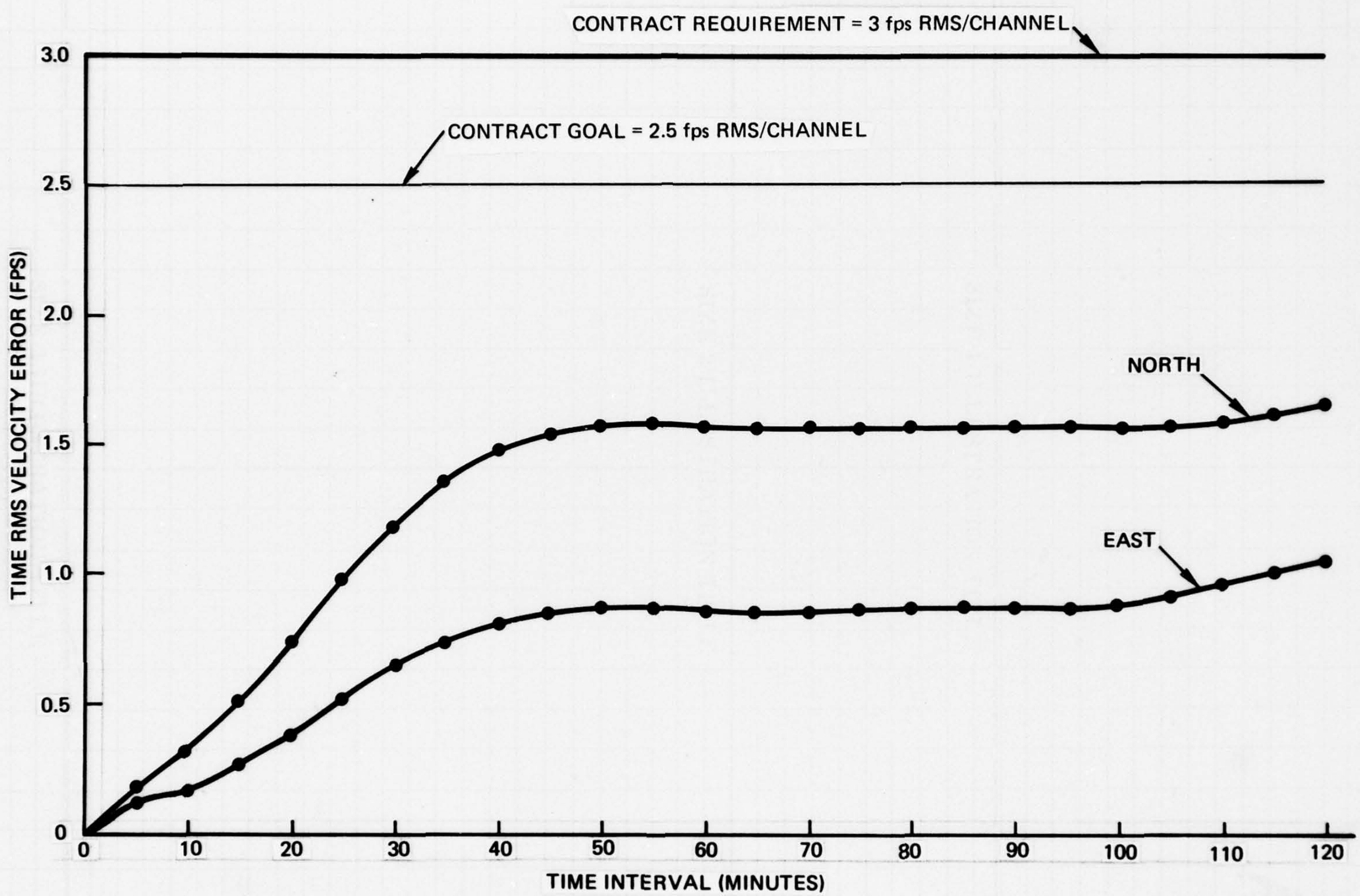


Figure N-2. EPM 1 Velocity Error Summary from Time t = 0 Indicated Time for 17 Navigation Runs

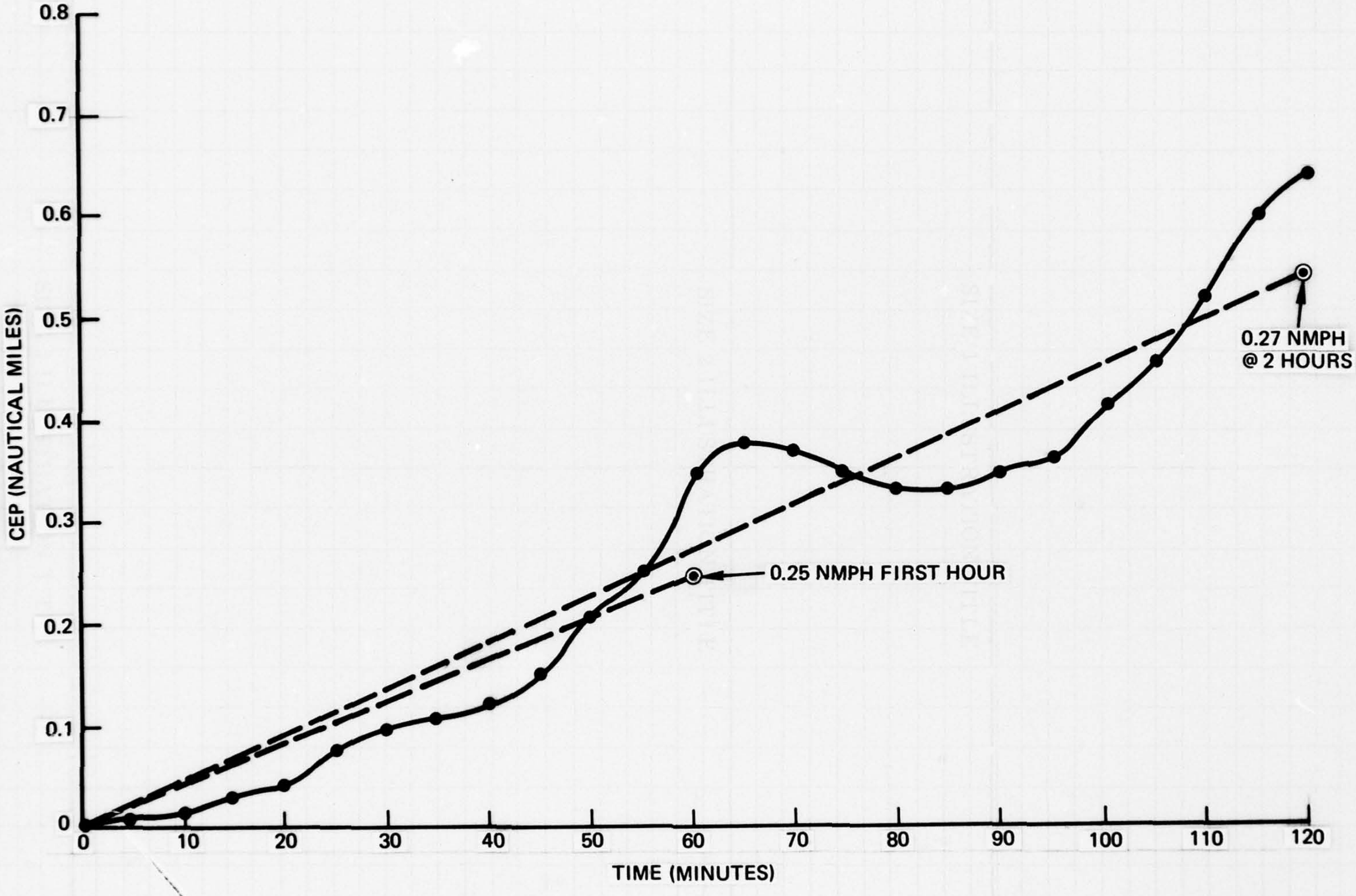


Figure N-3. EPM 2 Position Error Summary of 11 Navigation Runs

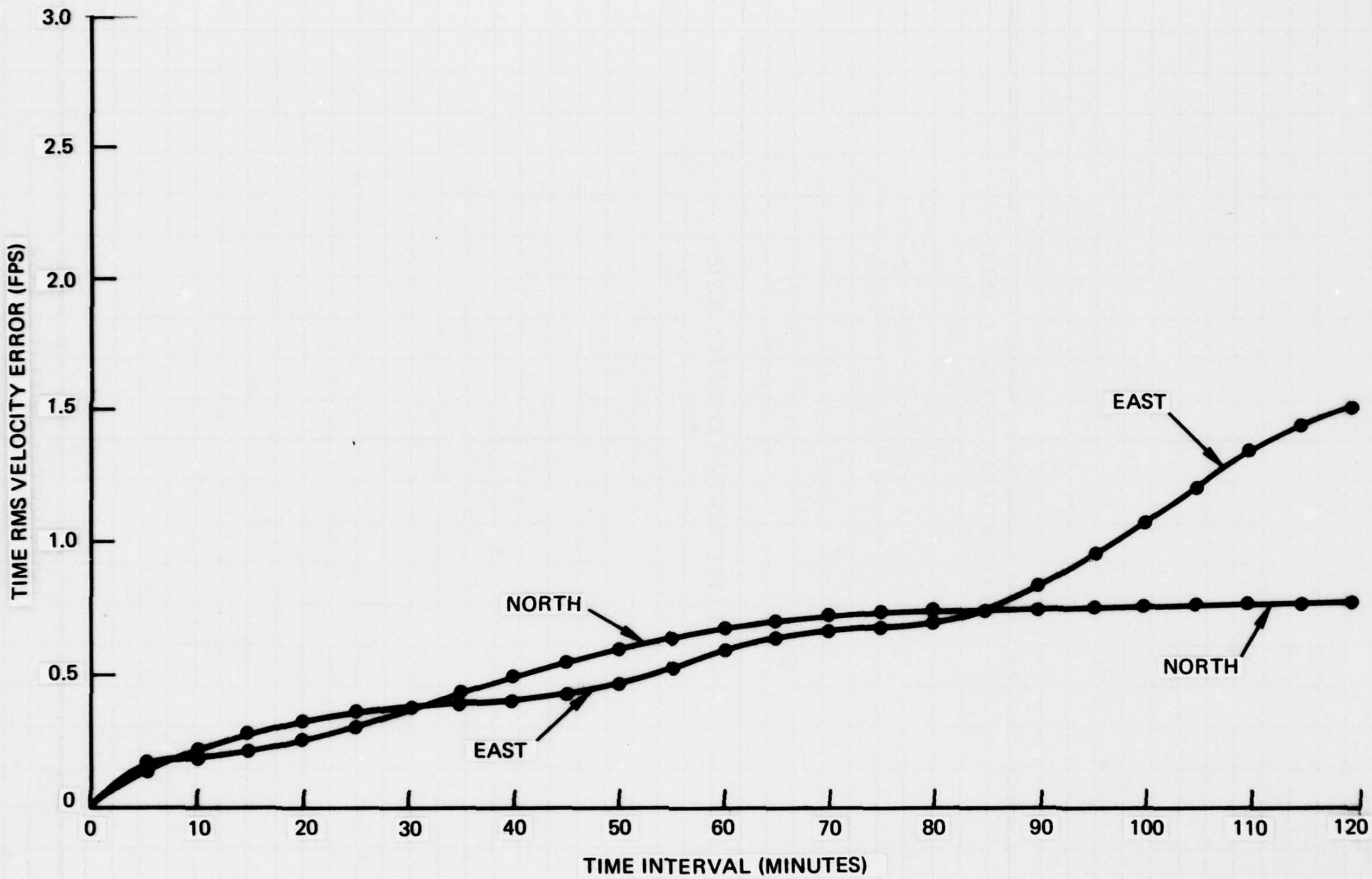


Figure N-4. EPM 2 Time RMS Velocity Error Summary From Time t = 0 to Indicated Time for 11 Navigation Runs

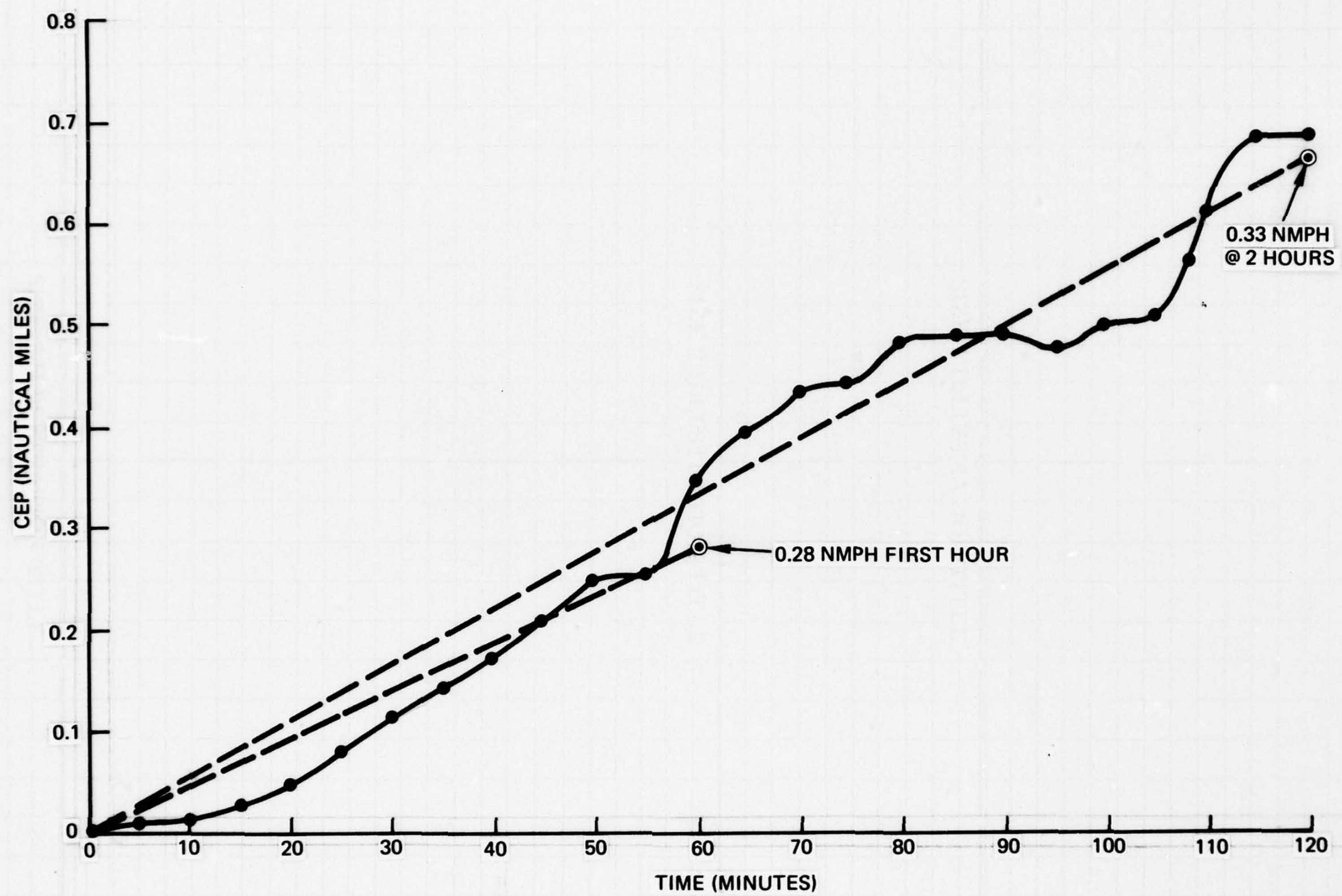


Figure N-5. EPM 1 and EPM 2 Position Error Summary for 28 Navigation Runs

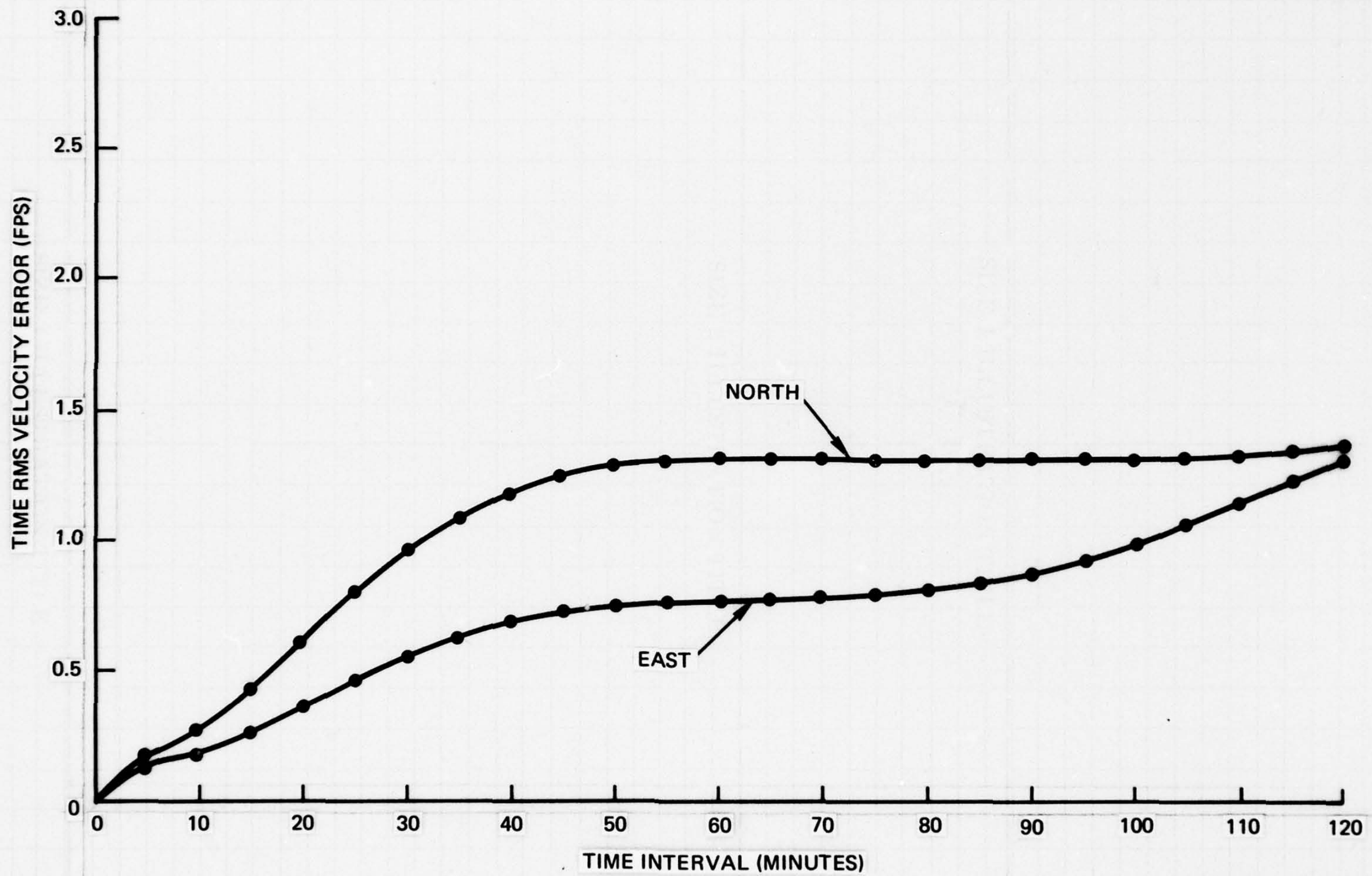


Figure N-6. EPM 1 and EPM 2 Time RMS Velocity Error Summary from Time t = 0 to Indicated Time for 28 Navigation Runs

Blank

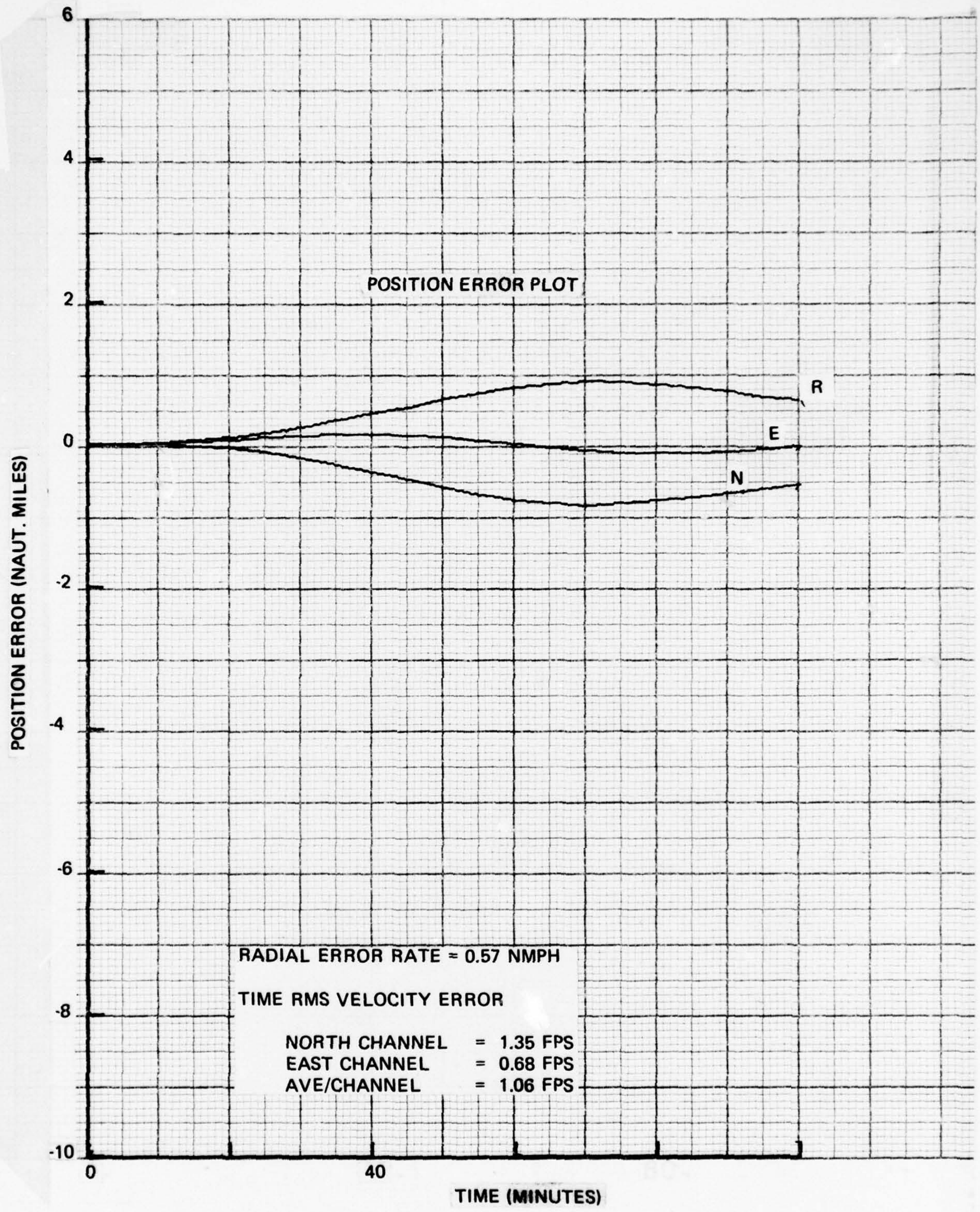
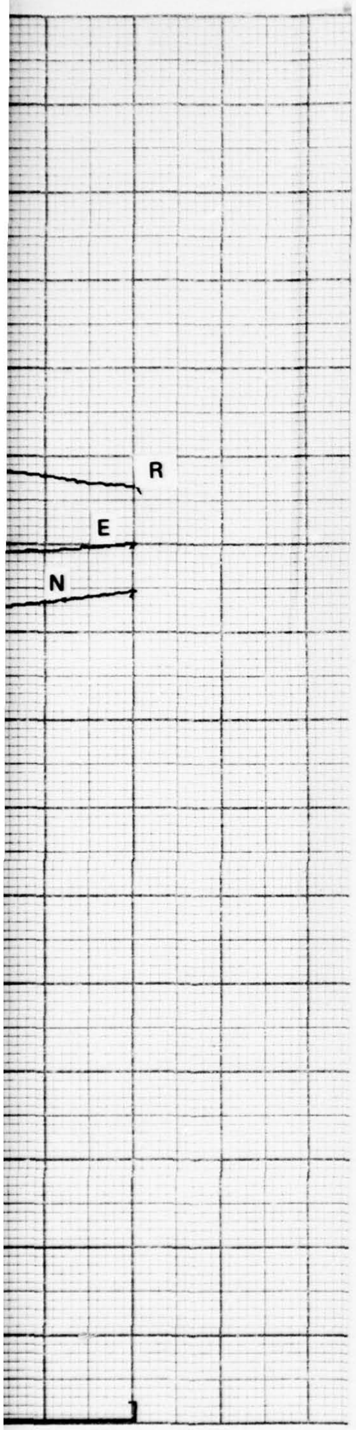
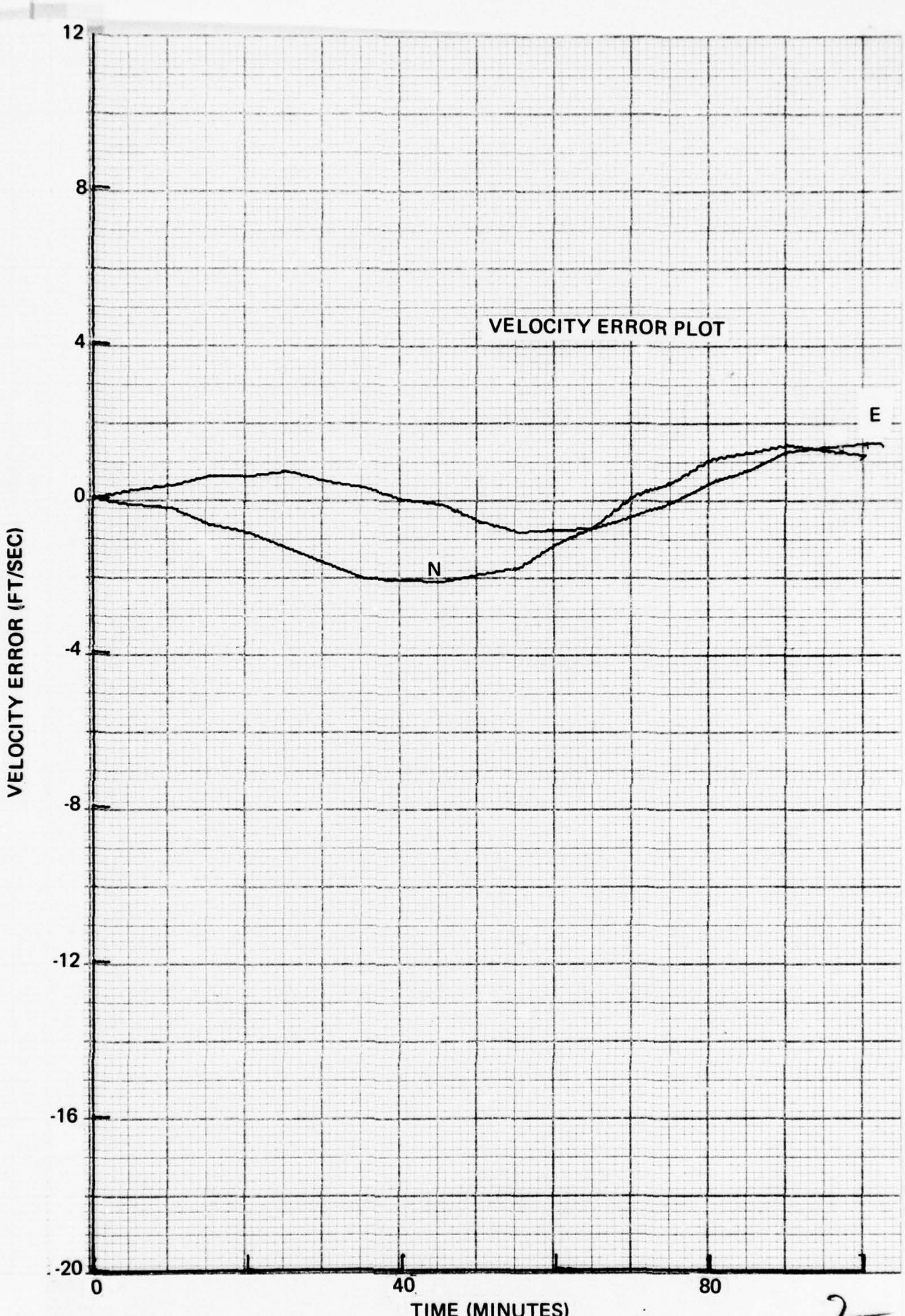


Figure N-7. EPM 1 NAV Run 1227766215, 0 Deg Heading


R
E
N


VELOCITY ERROR PLOT
12
8
4
0
-4
-8
-12
-16
-20
VELOCITY ERROR (FT/SEC)
E
N
0
40
80
TIME (MINUTES)

2

ding

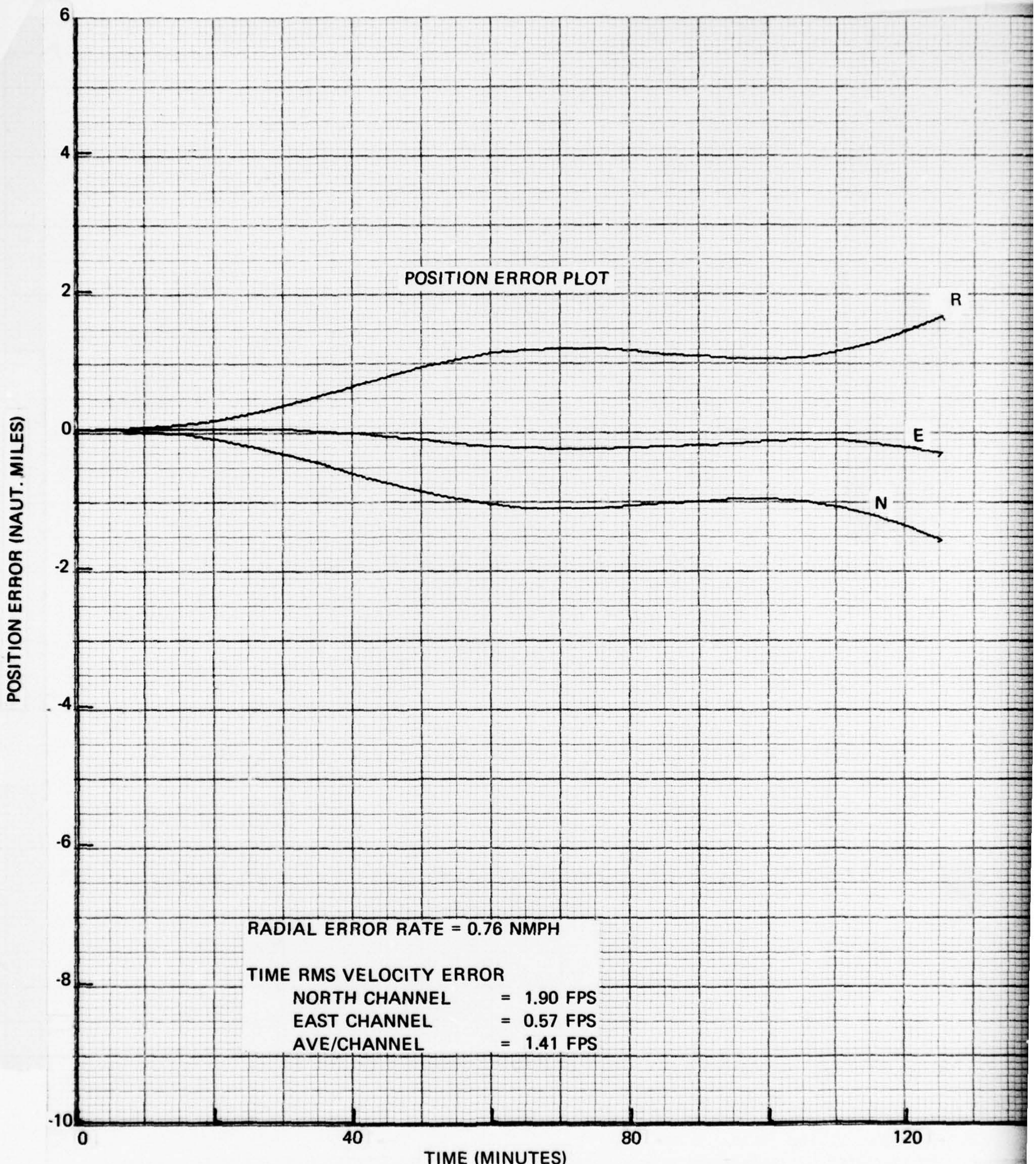
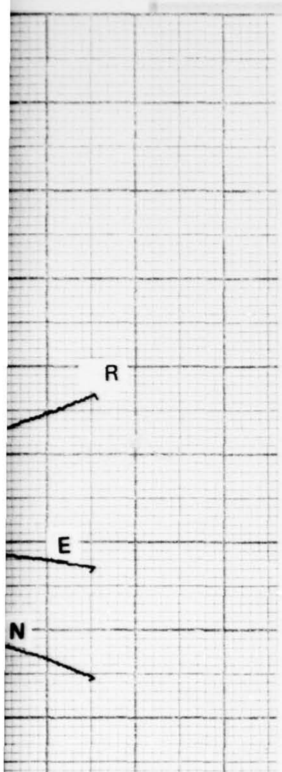
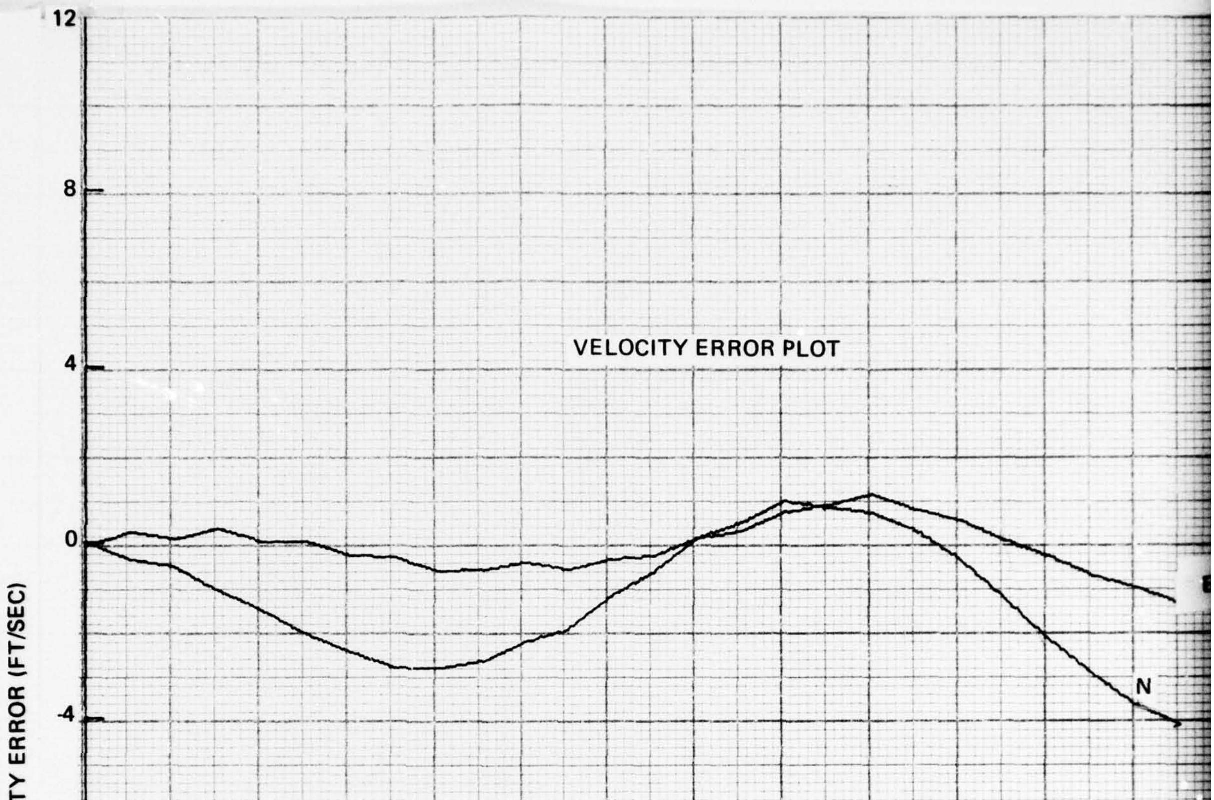


Figure N-8. EPM 1 NAV Run 1228760545, 0 Deg Heading


R
E
N
120


VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
12
8
4
0
-4
-8
-12
-16
-20
N
0
40
80
120
TIME (MINUTES)

2

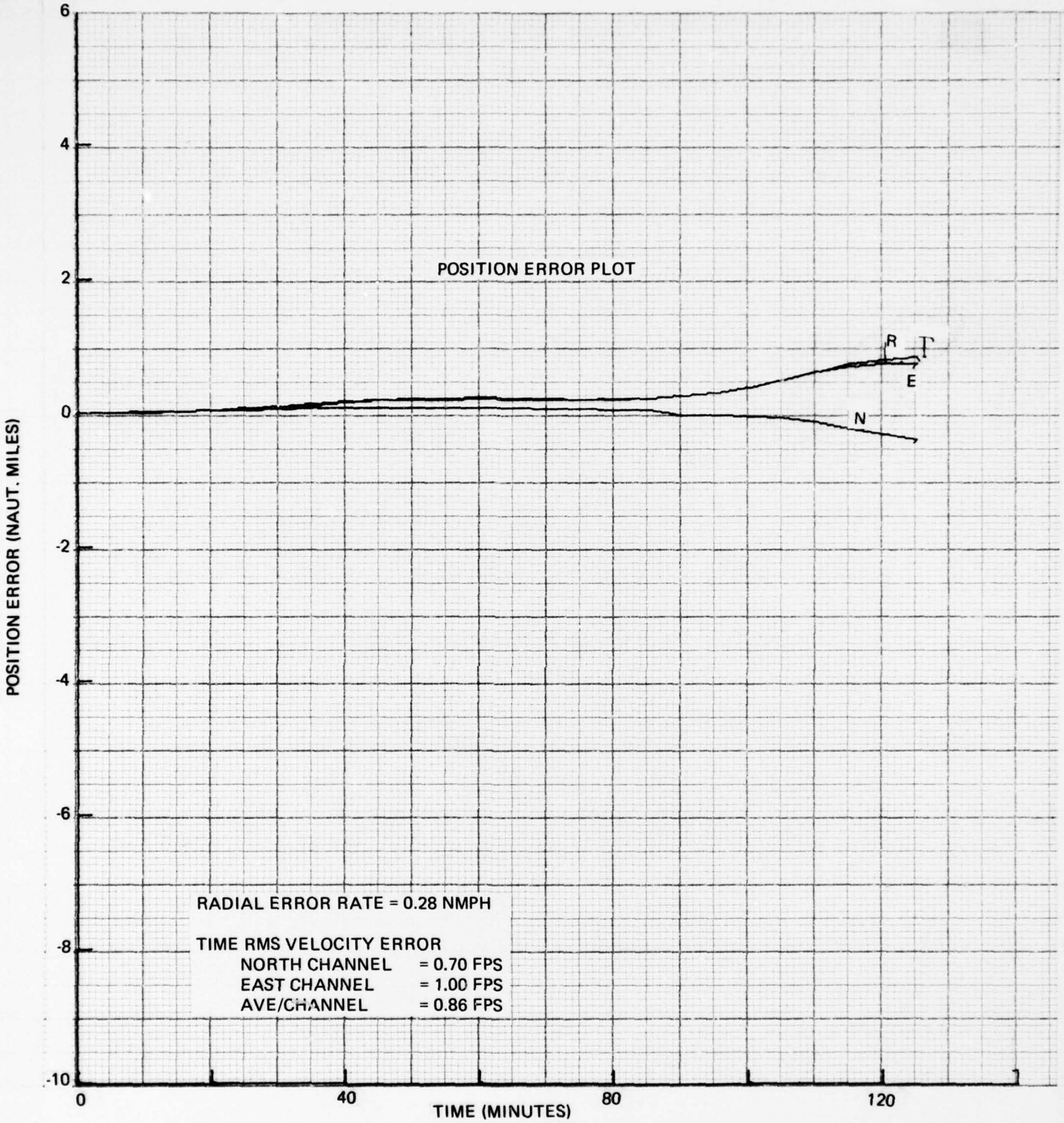
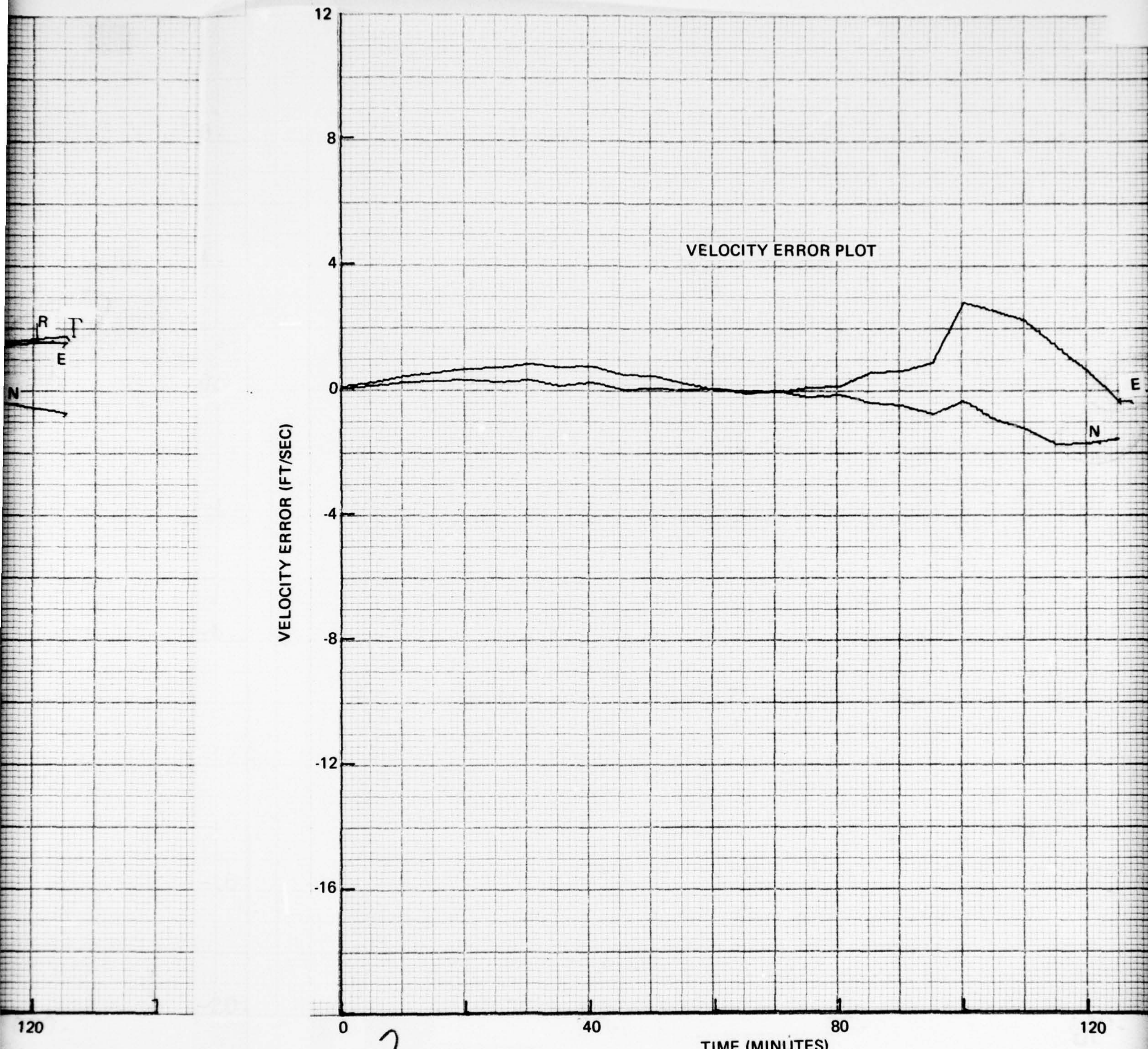


Figure N-9. EPM 1 NAV Run 1229760541, 90 Deg Heading


VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
TIME (MINUTES)
12
8
4
0
-4
-8
-12
-16
0
40
80
120
E
N
R

2

UJ

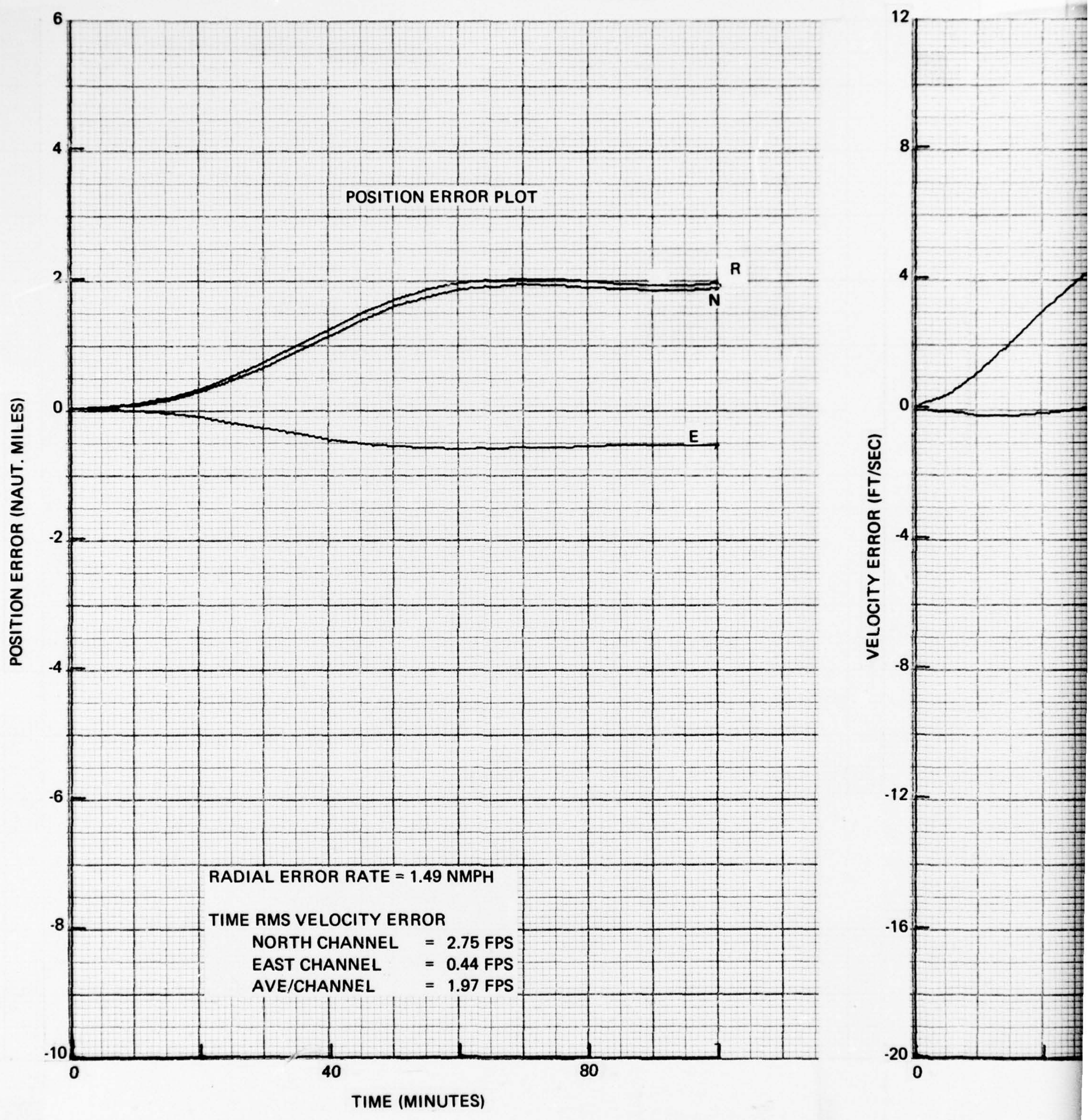
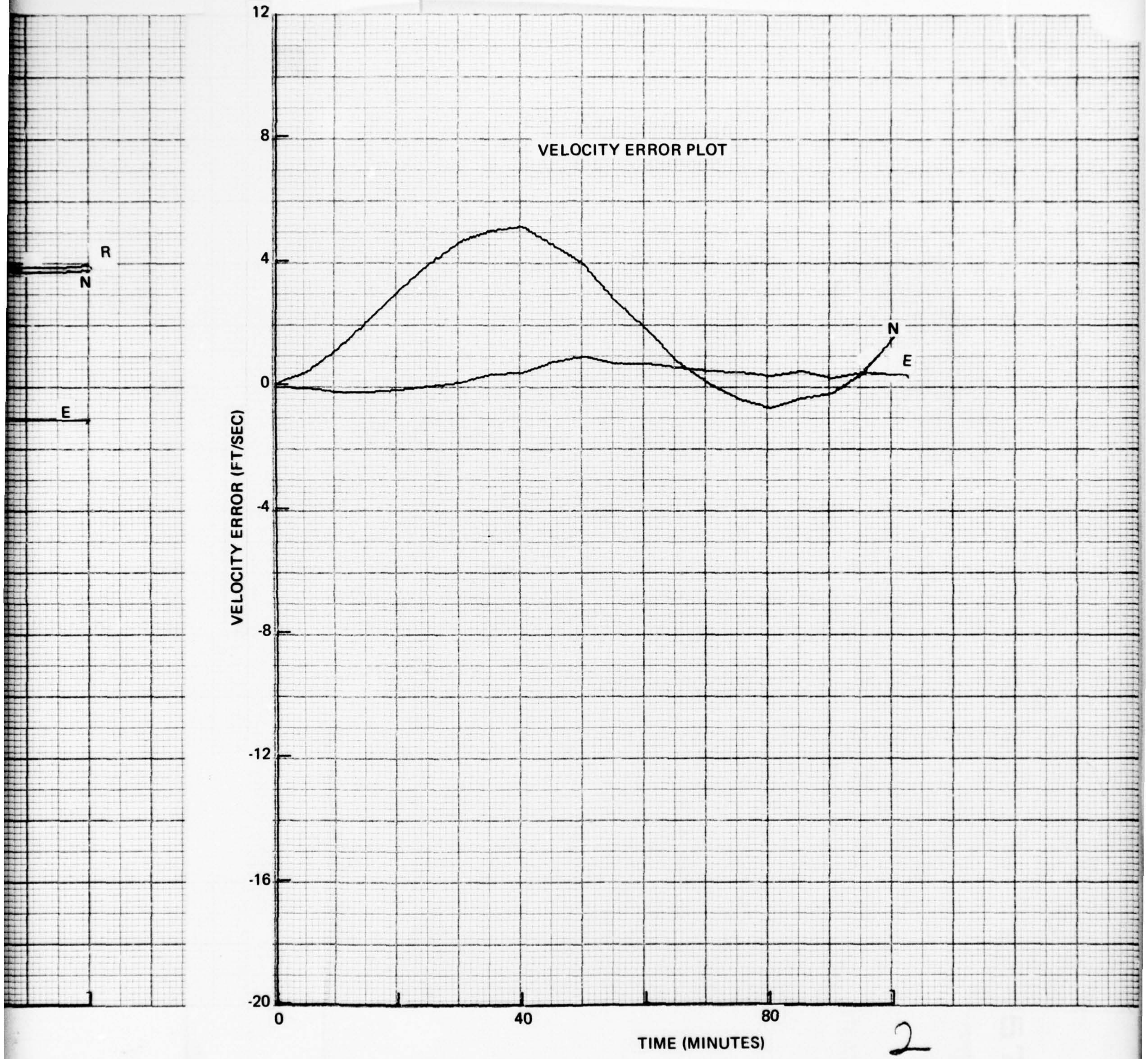


Figure N-10. EPM 1 NAV Run 1230760327, 0 Deg Heading



, 0 Deg Heading

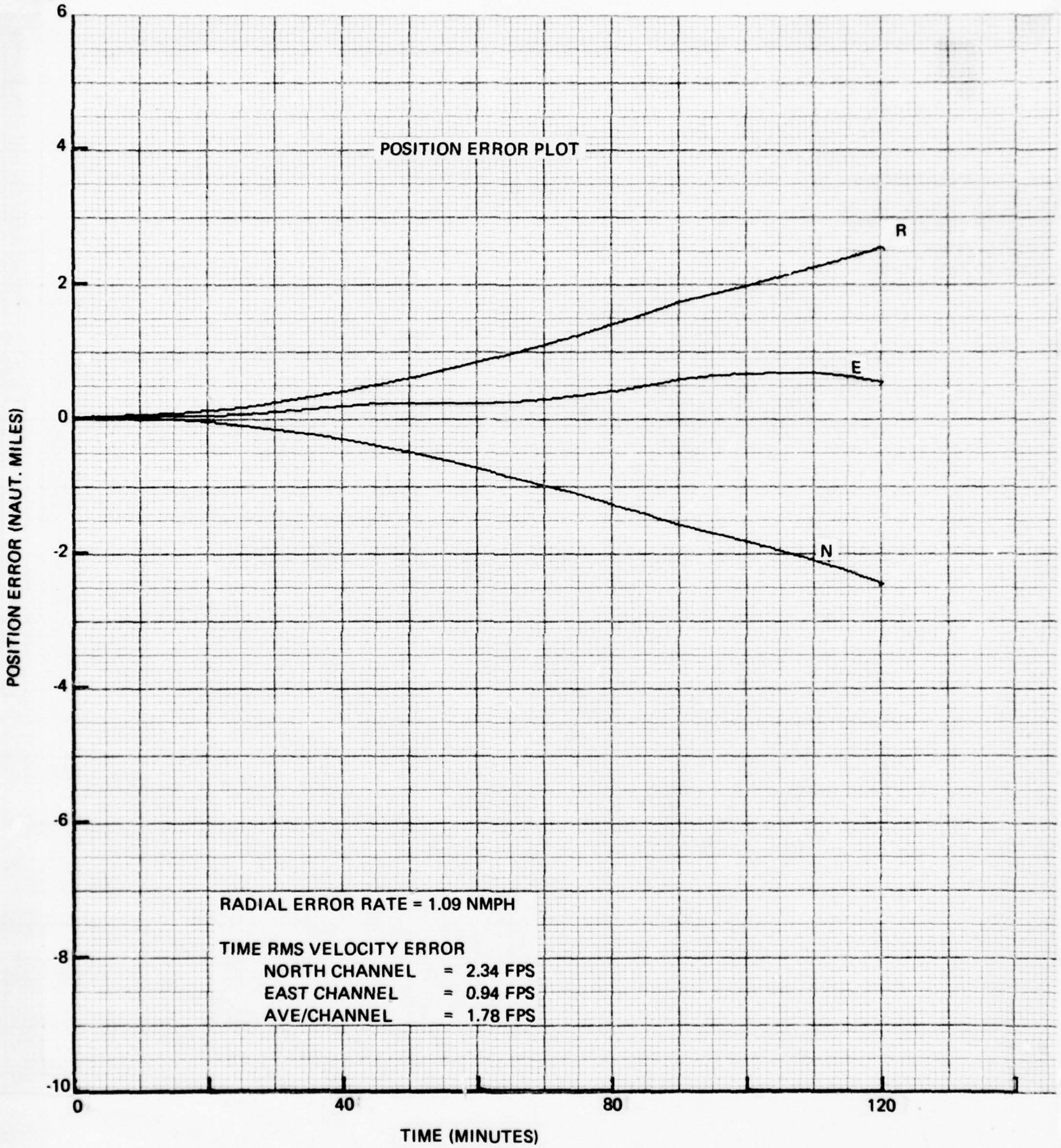
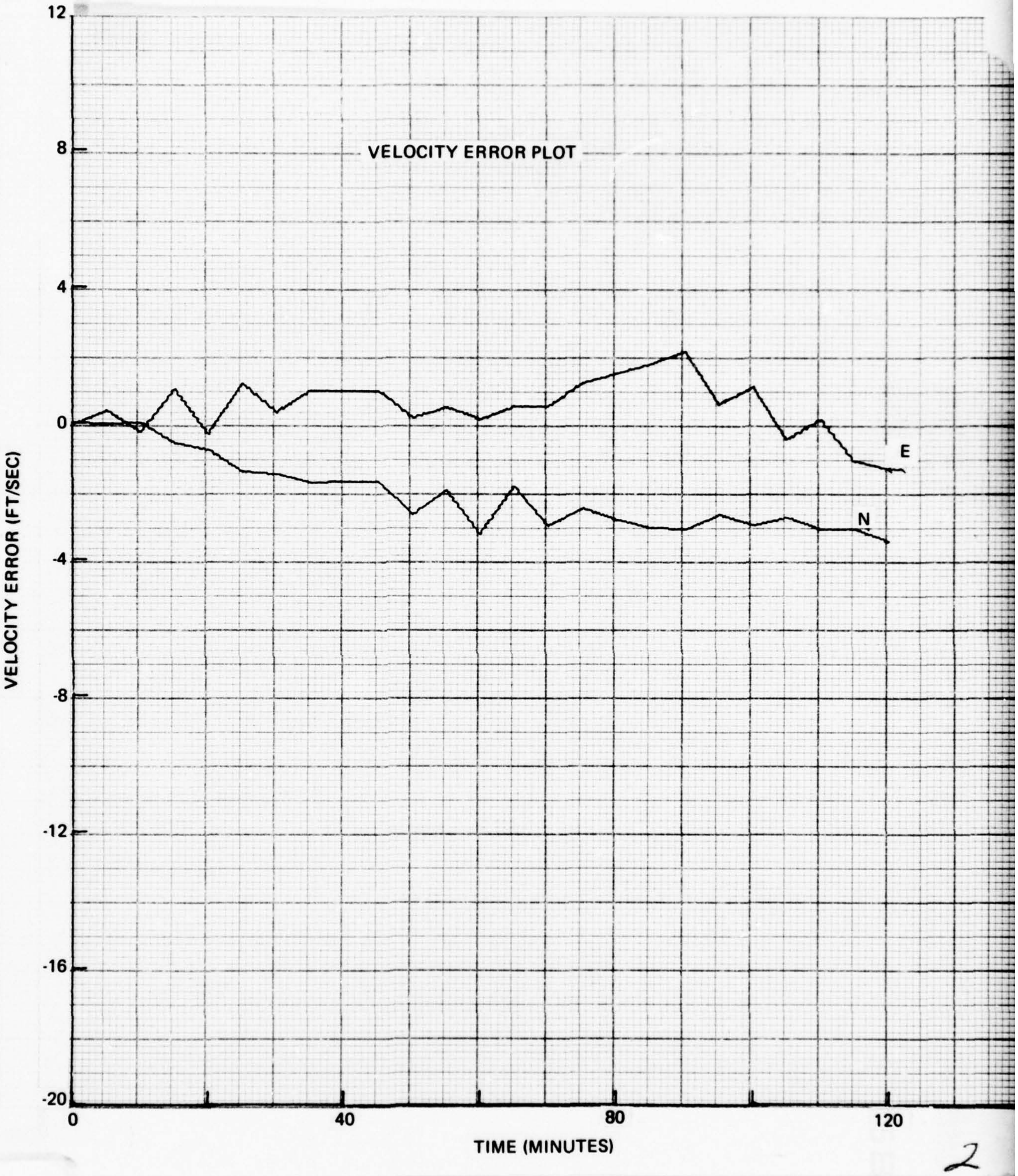


Figure N-11. EPM 1 NAV Run 1230761825, 0 Deg Heading


VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
12
8
4
0
-4
-8
-12
-16
-20
0
40
80
120
TIME (MINUTES)
E
N

2

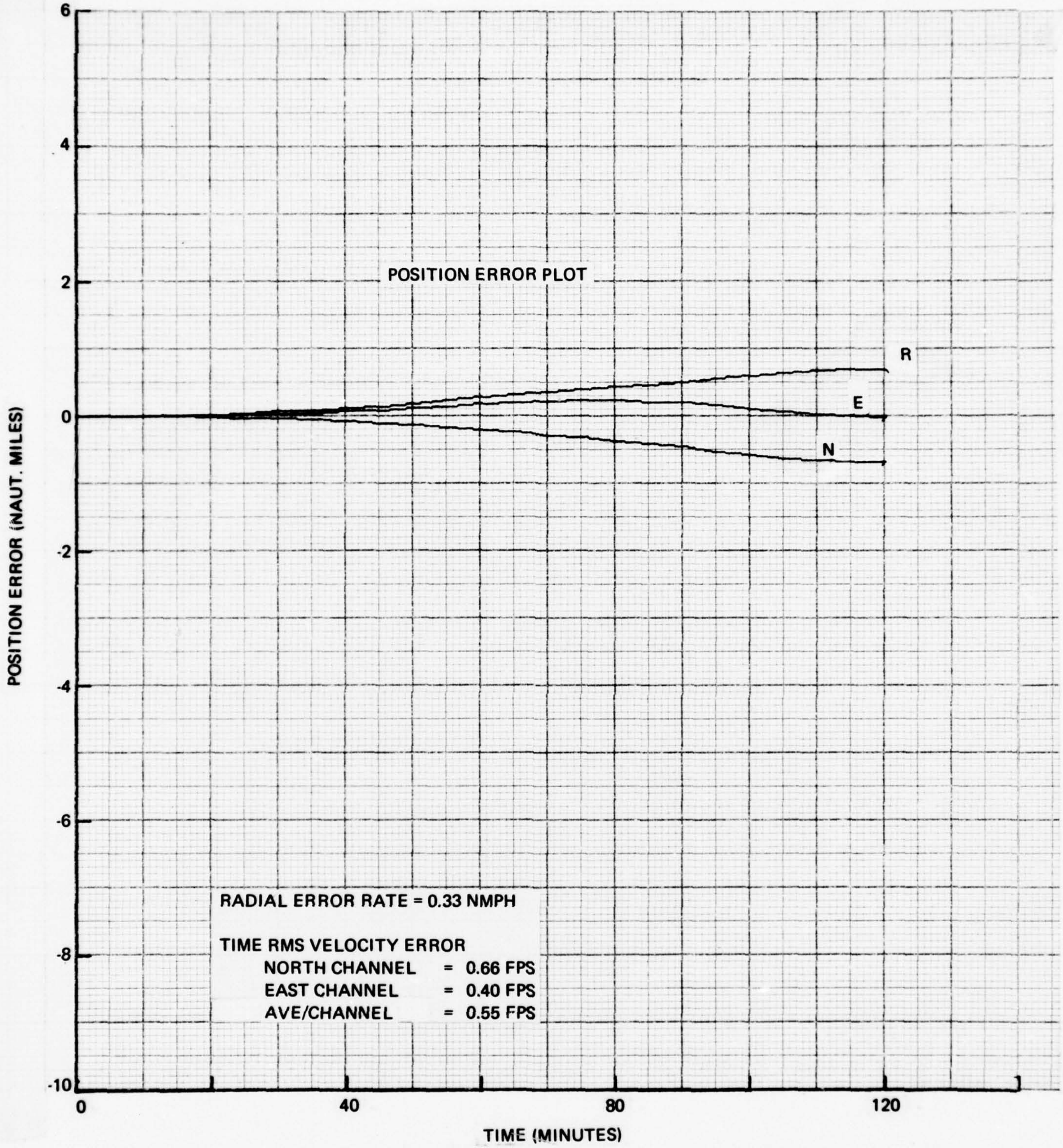
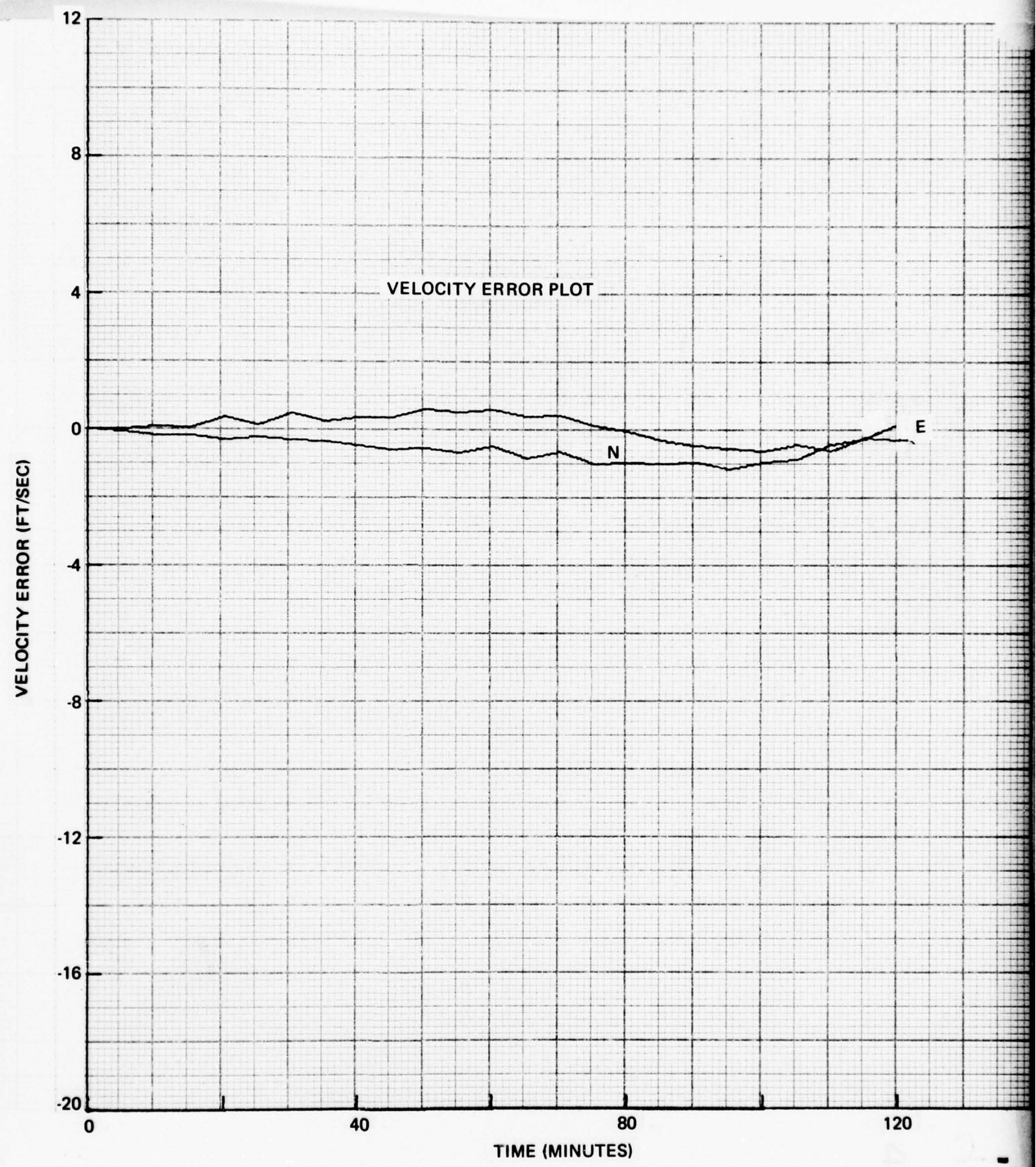


Figure N-12. EPM 1 NAV Run 1230762239, 180 Deg Heading


VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
12
8
4
0
-4
-8
-12
-16
-20
N
E
0
40
80
120
TIME (MINUTES)

2

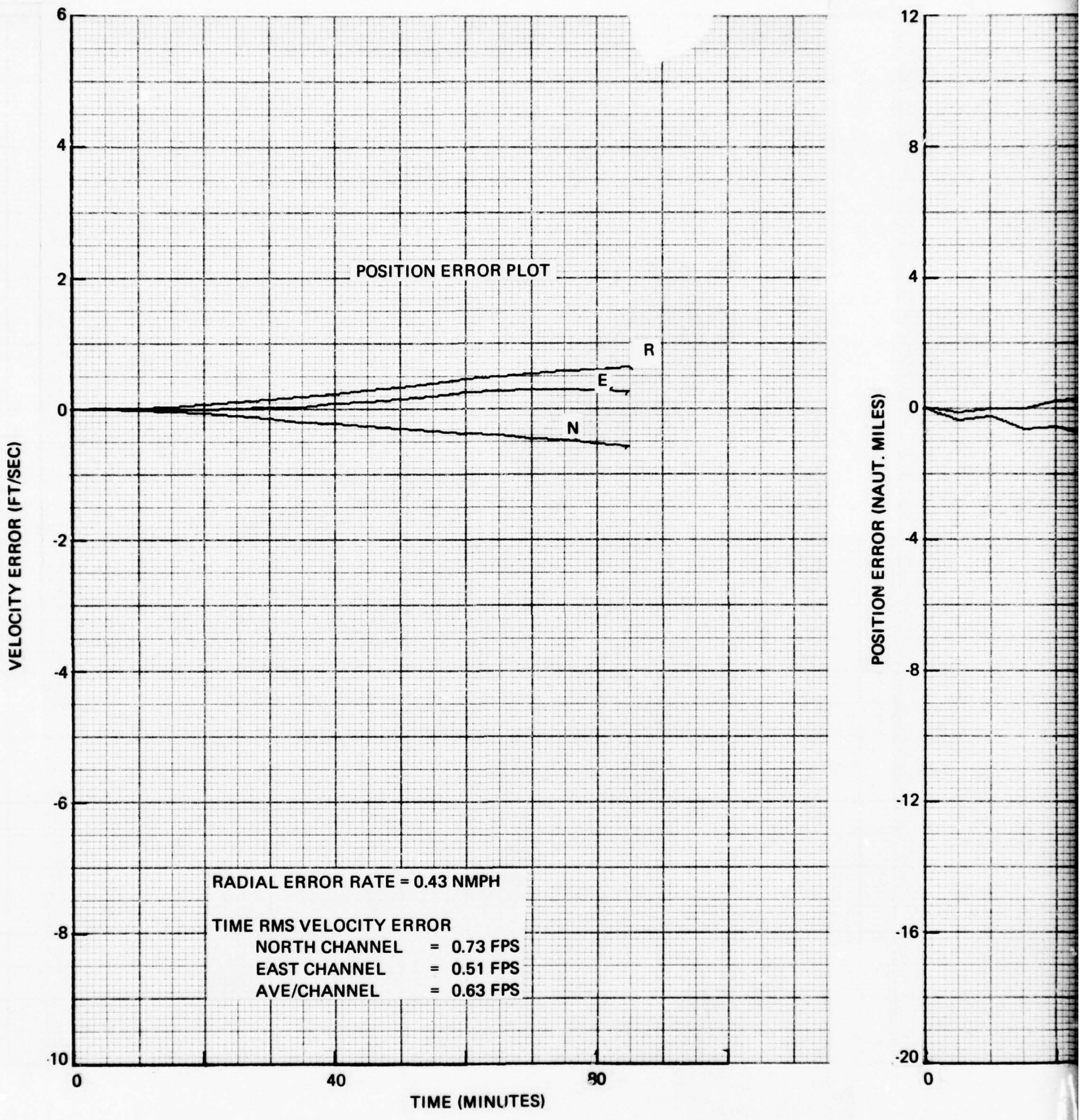
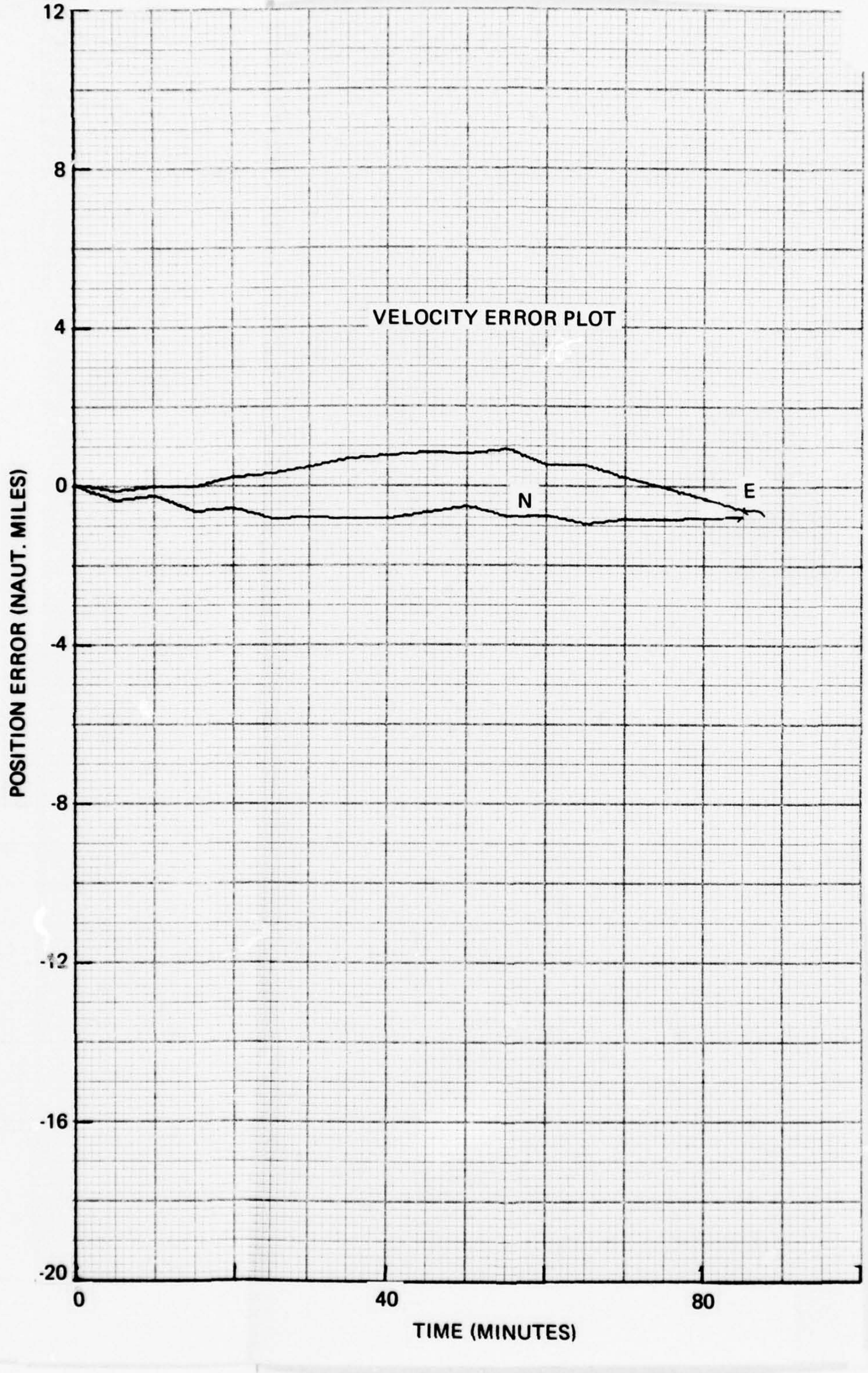


Figure N-13. EPM 1 NAV Run 0102770229, 270 Deg Heading



2

0 Deg Heading

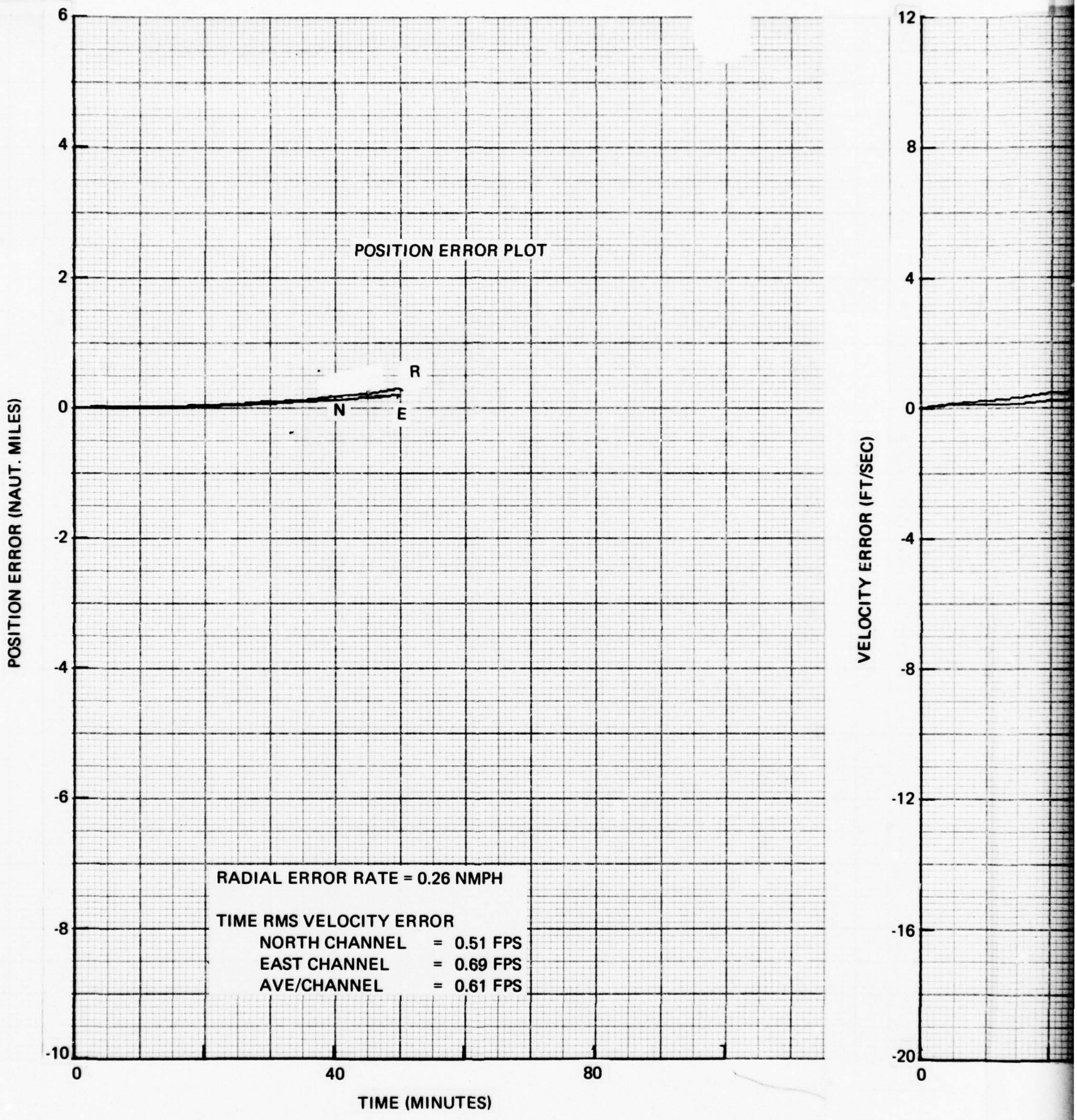
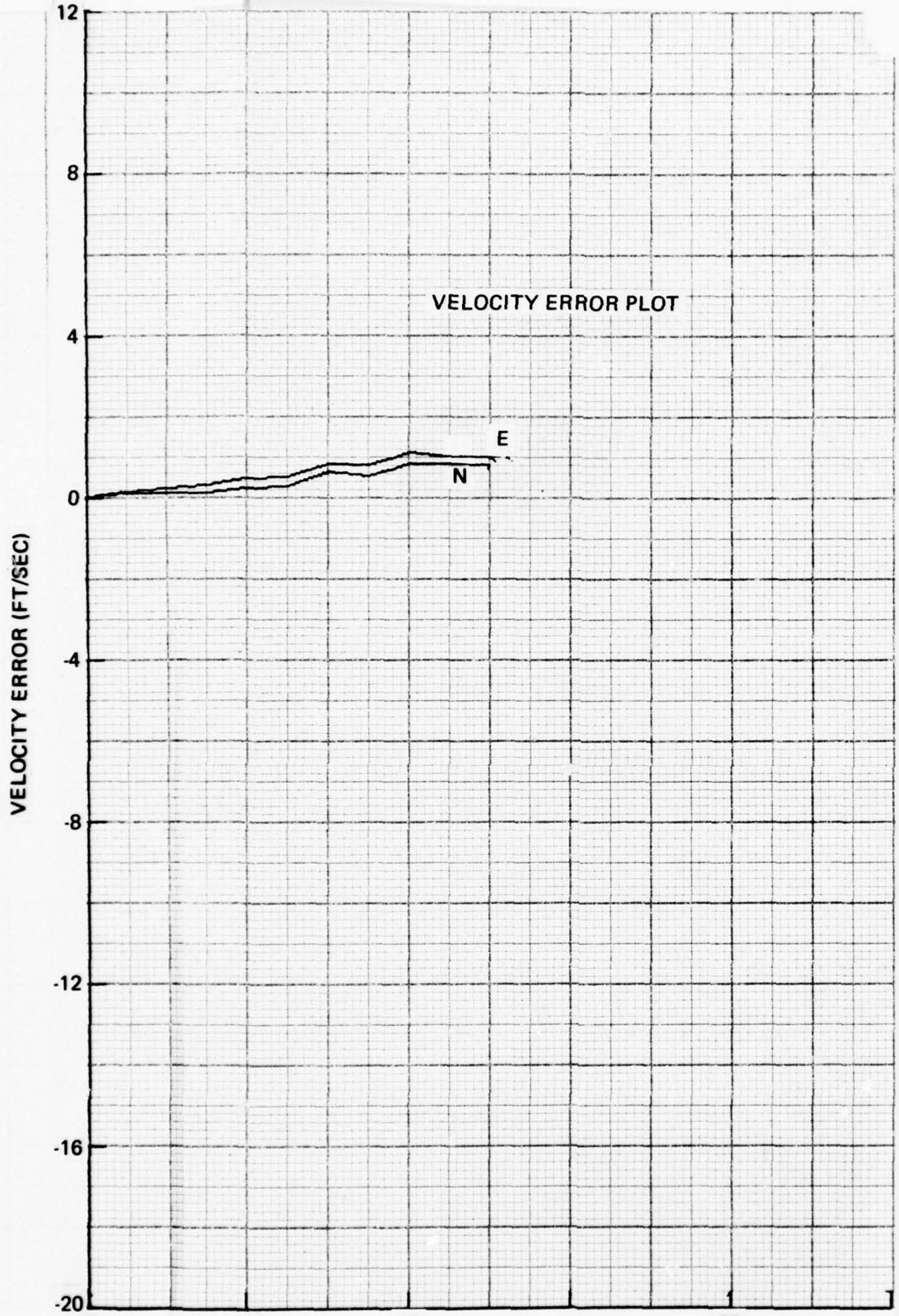


Figure N-14. EPM 1 NAV Run 0102770428, 270 Deg Heading



VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
12
8
4
0
-4
-8
-12
-16
-20
E
N
0
40
80
TIME (MINUTES)

2

Heading

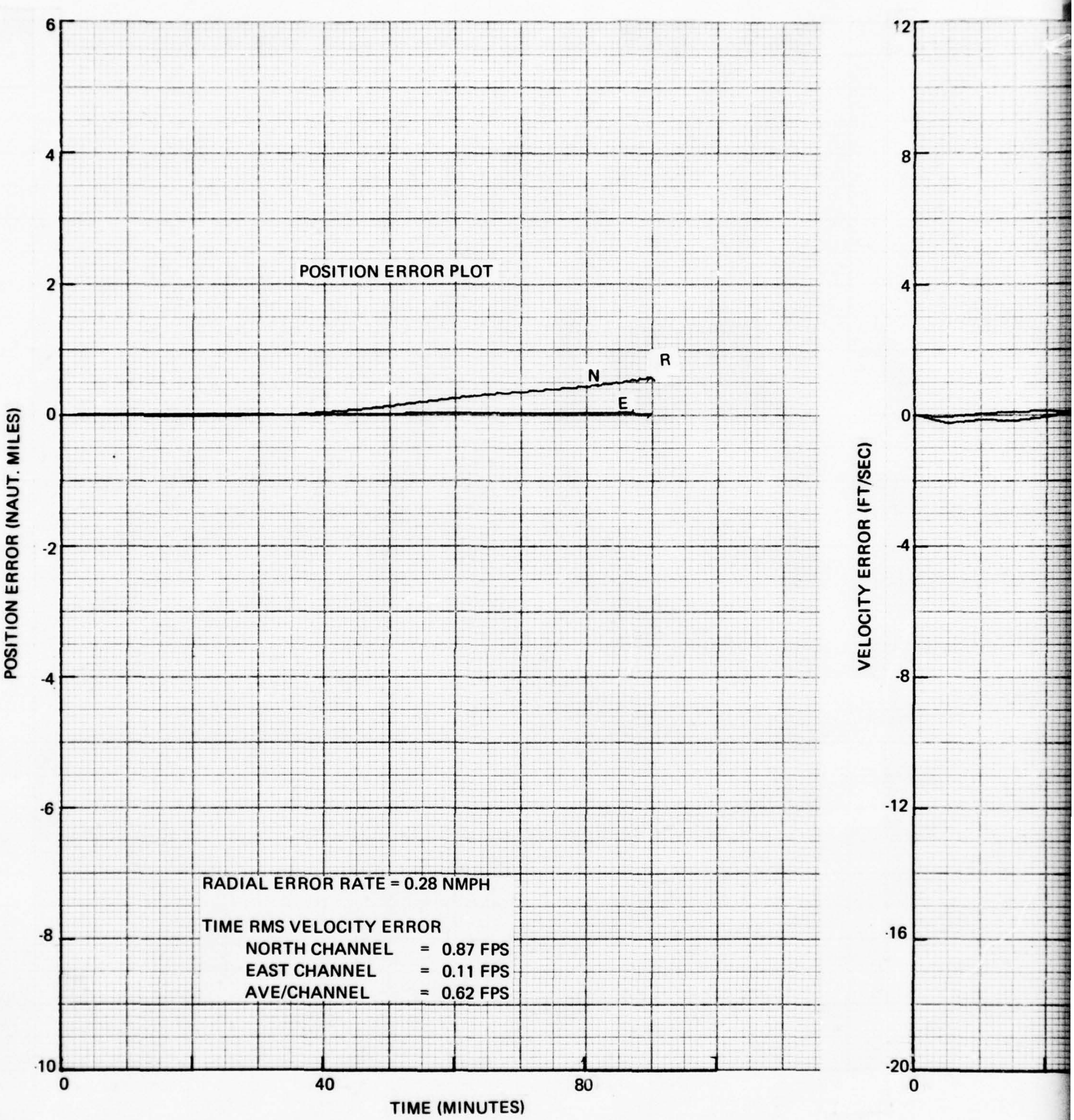
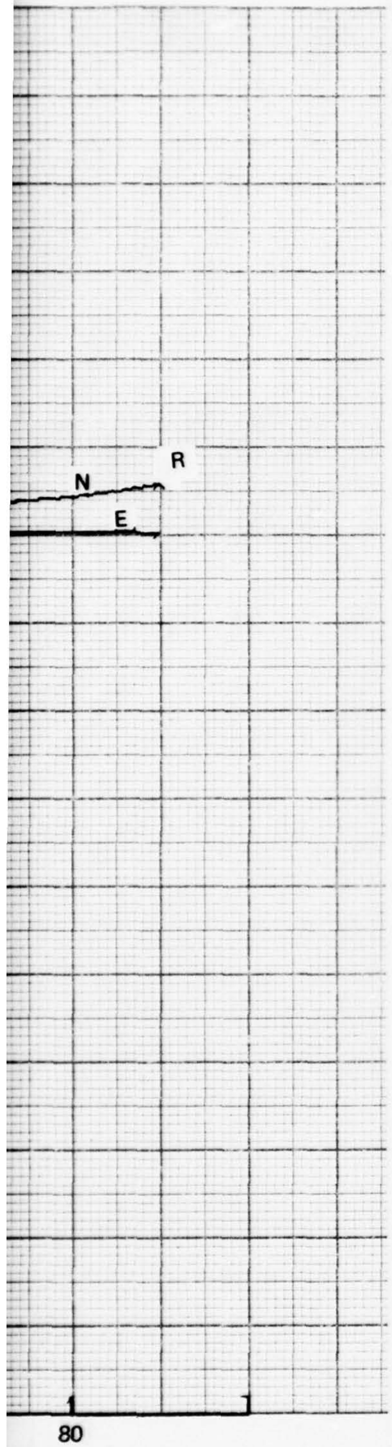
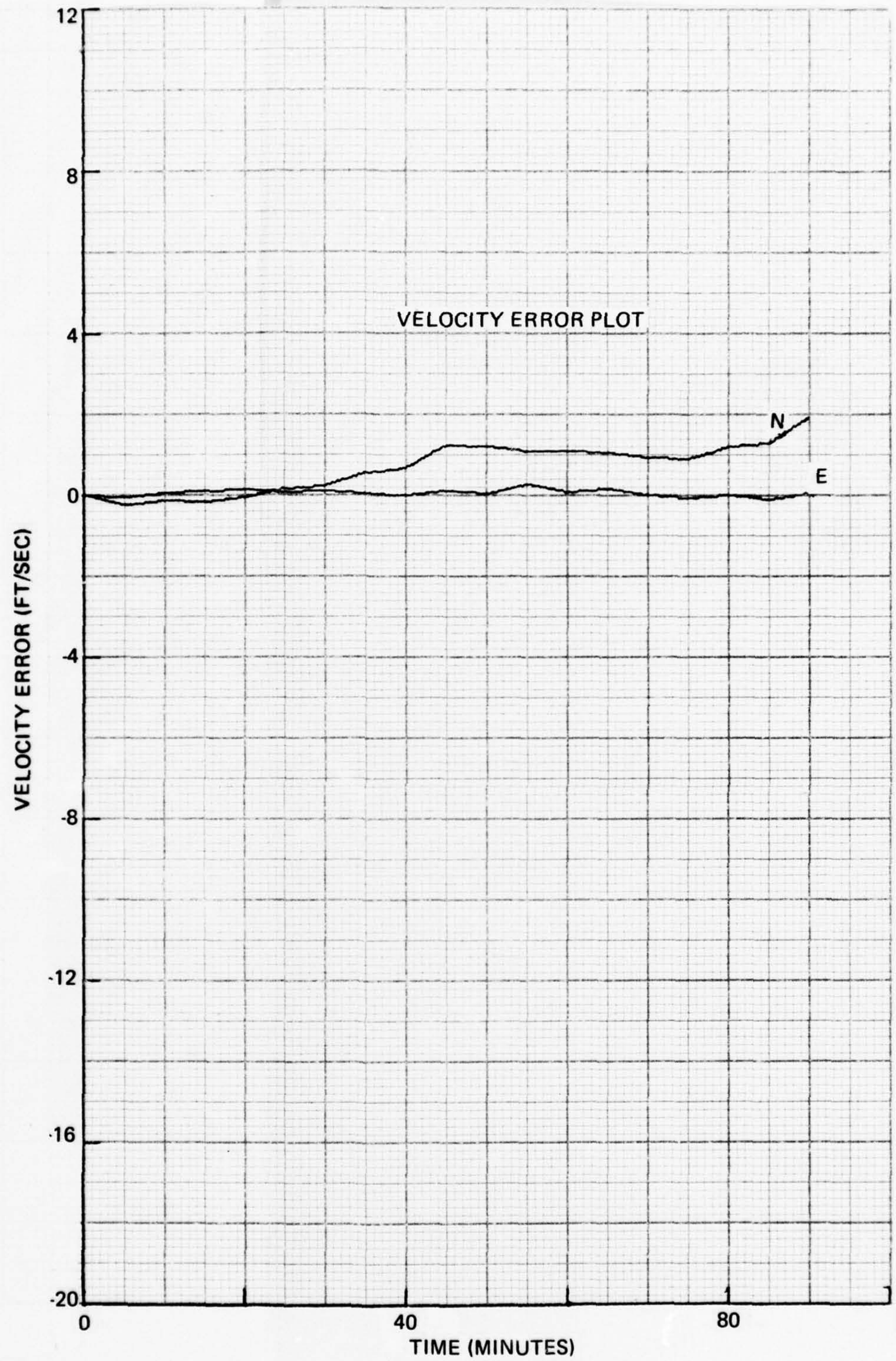


Figure N-15. EPM 1 NAV Run 0102770604, 270 Deg Heading

1





)102770604, 270 Deg Heading

2

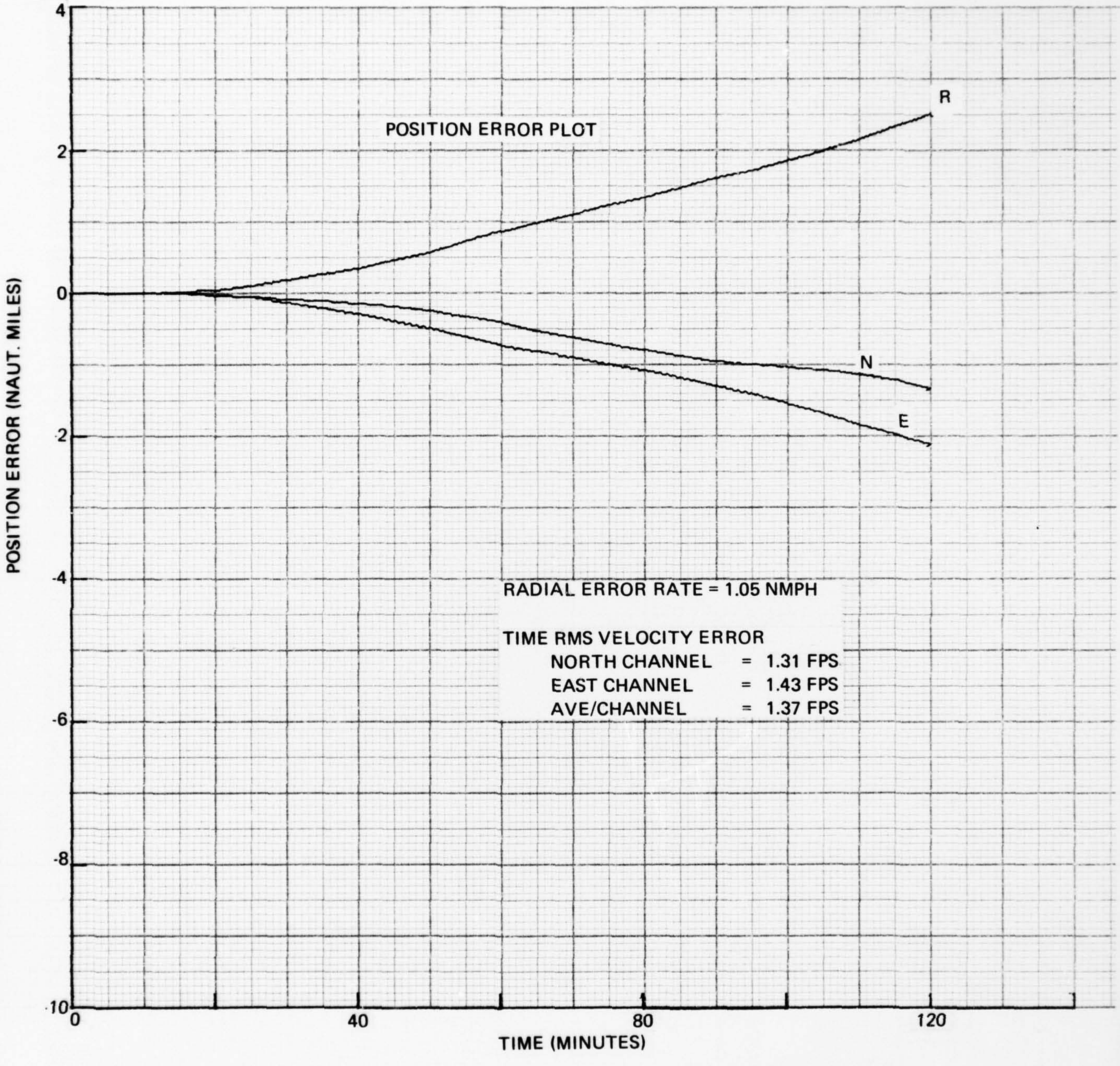
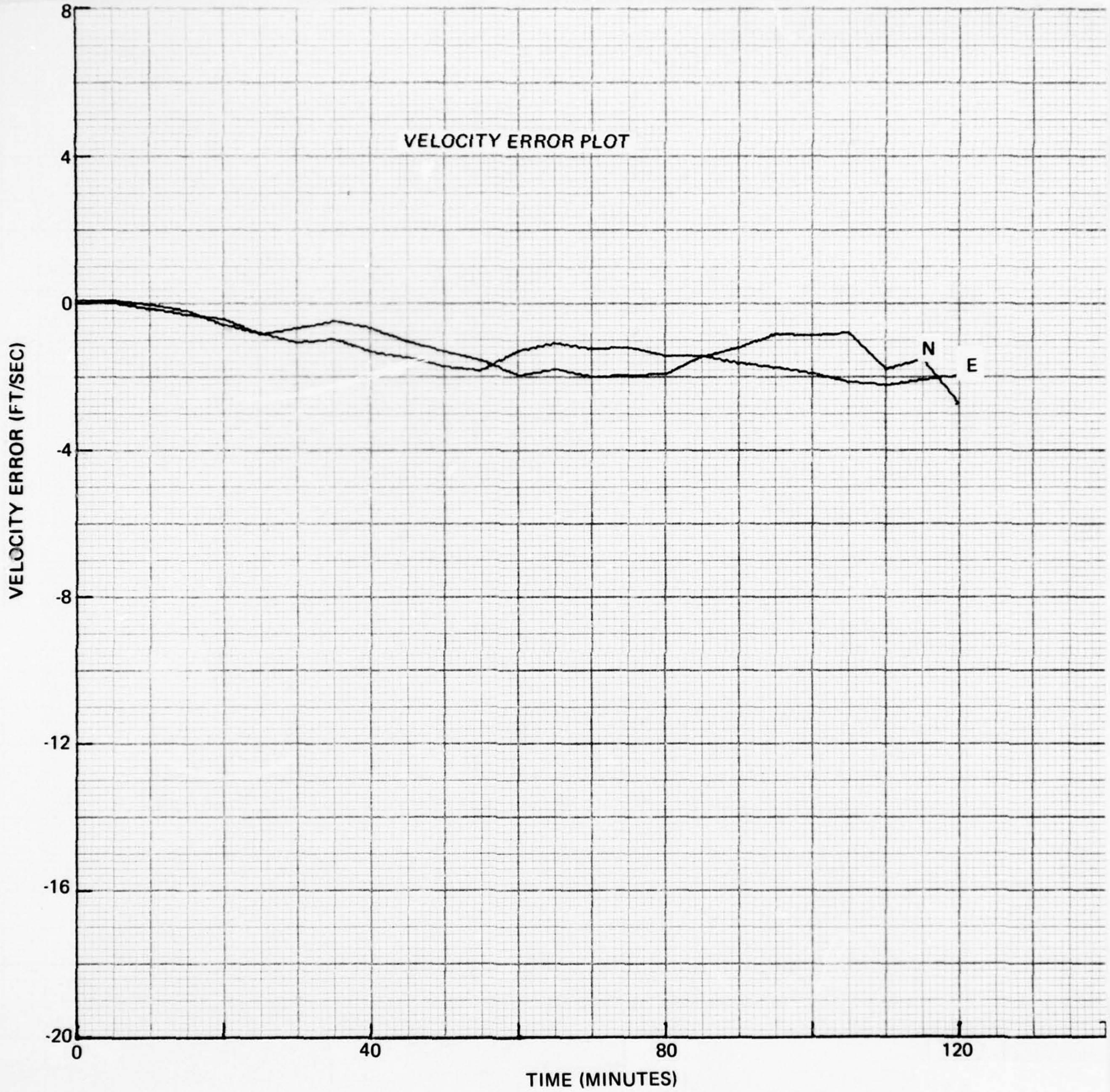


Figure N-16. EPM 1 NAV Run 0112770203, 0 Deg Heading

1


VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
8
4
0
-4
-8
-12
-16
-20
0
40
80
120
TIME (MINUTES)
N
E

2

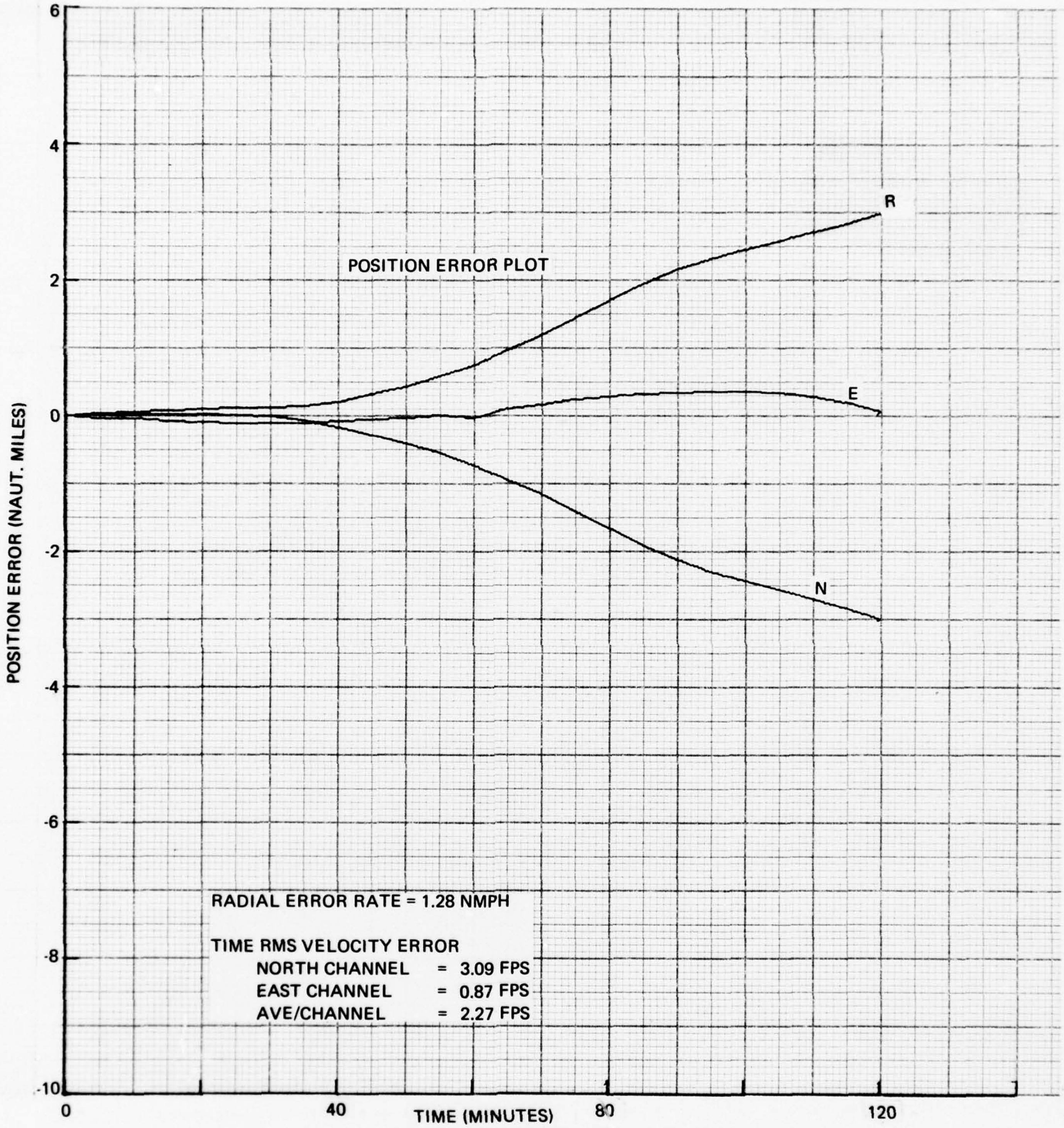
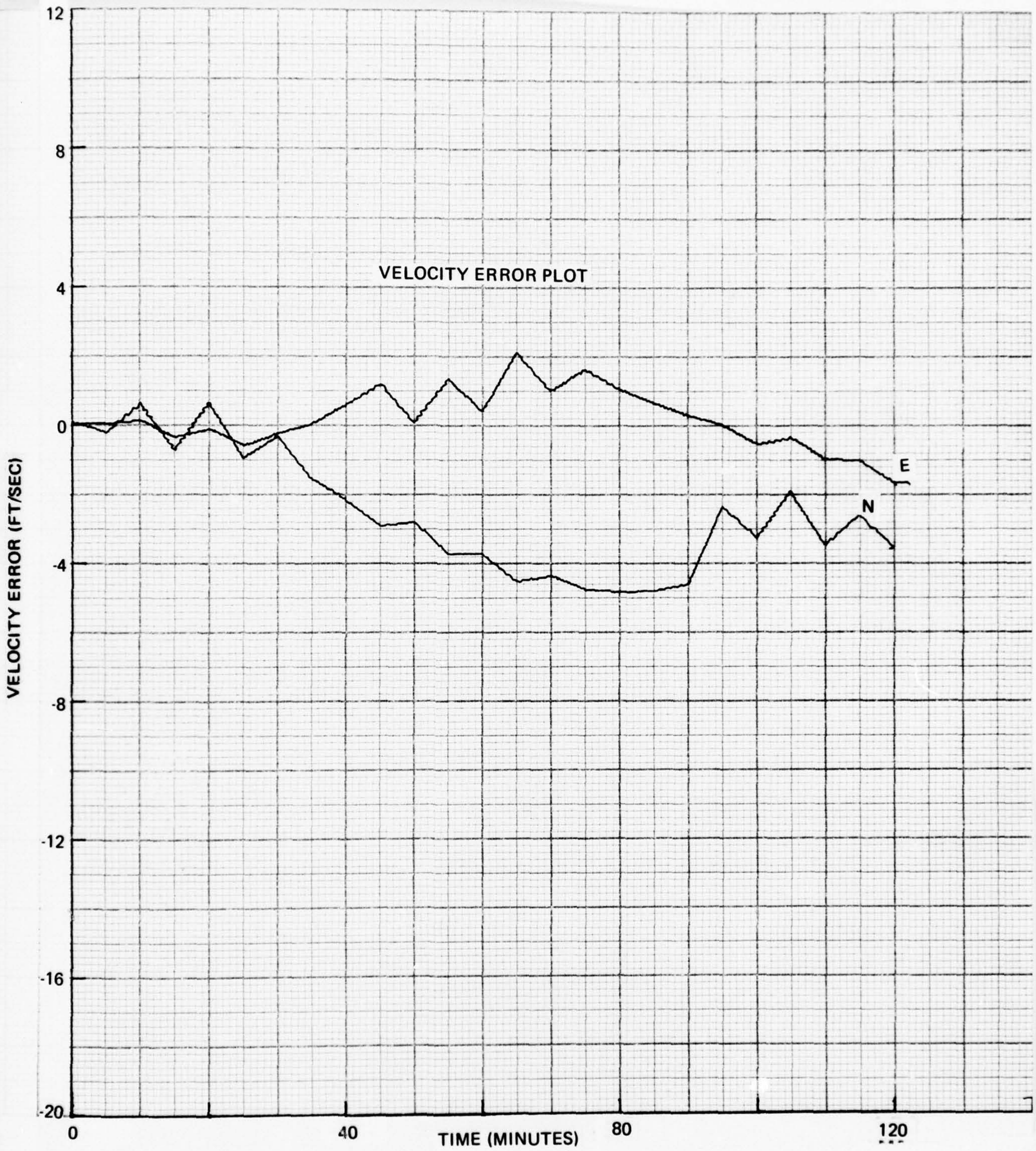


Figure N-17. EPM 1 NAV Run 0112770630, 90 Deg Heading

1



VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
12
8
4
0
-4
-8
-12
-16
-20
0
40
80
120
TIME (MINUTES)
E
N

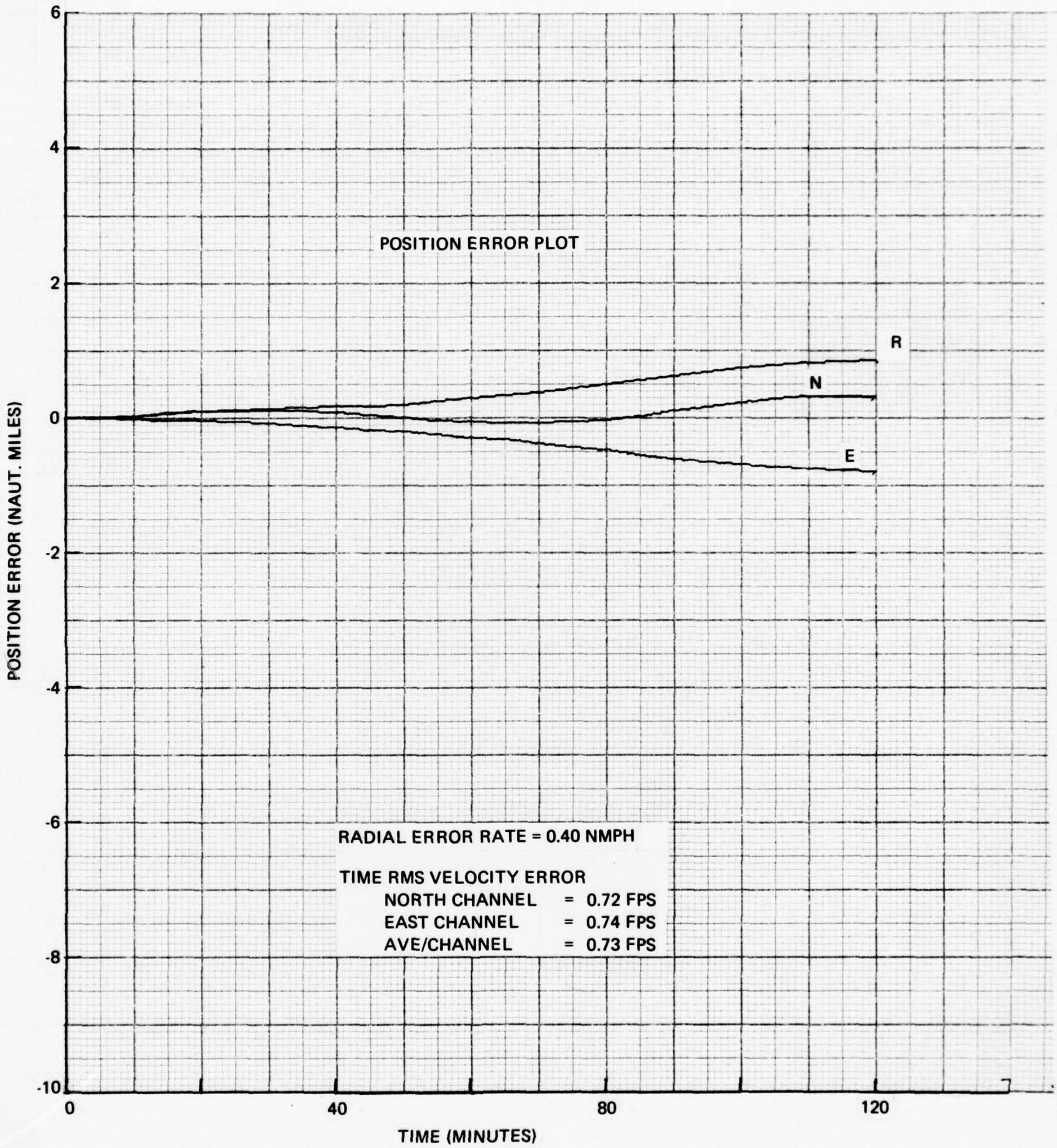
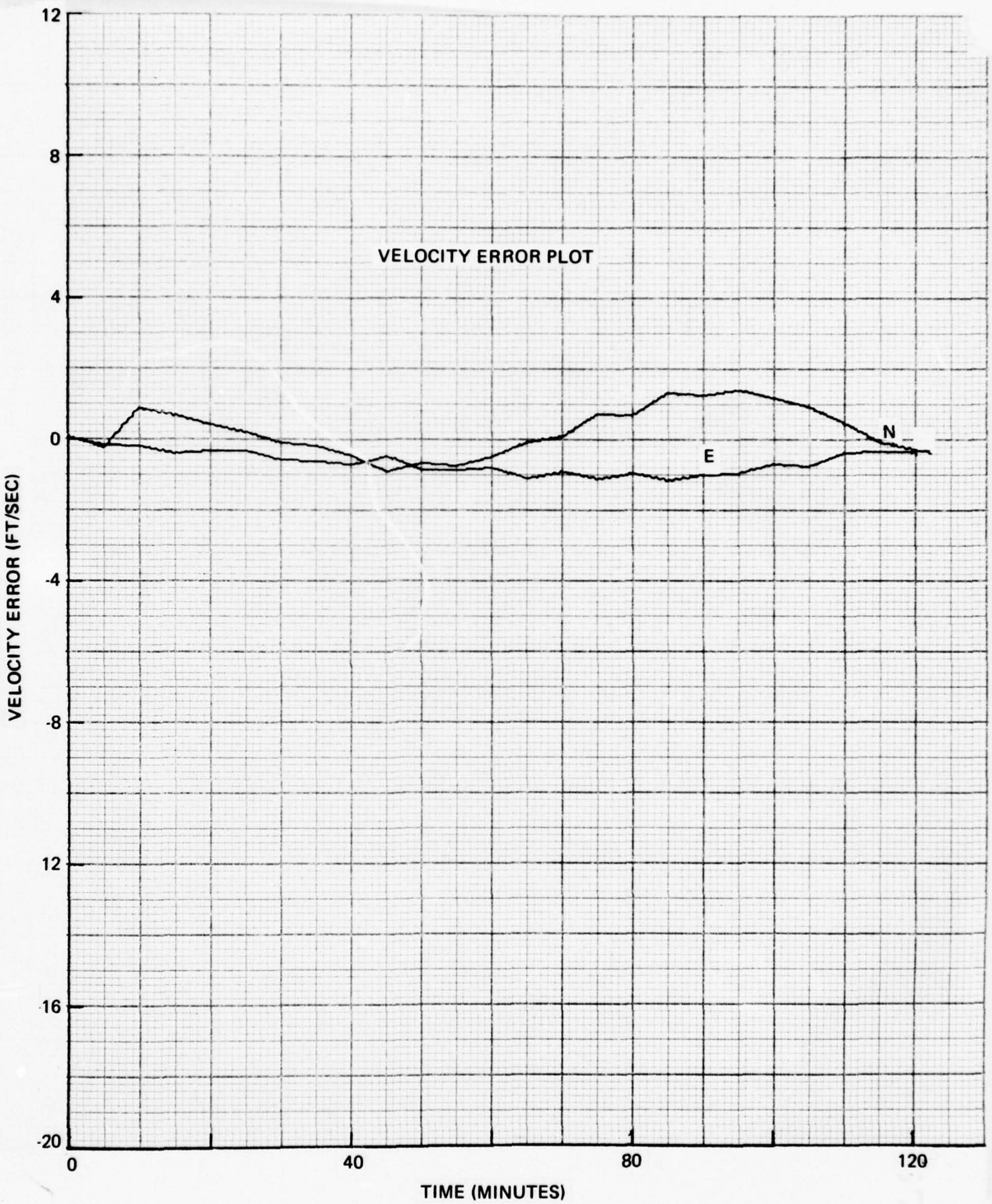


Figure N-18. EPM 1 NAV Run 0214772013, 0 Deg Heading

1


VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
12
8
4
0
-4
-8
12
-16
-20
0
40
80
120
TIME (MINUTES)
N
E

2

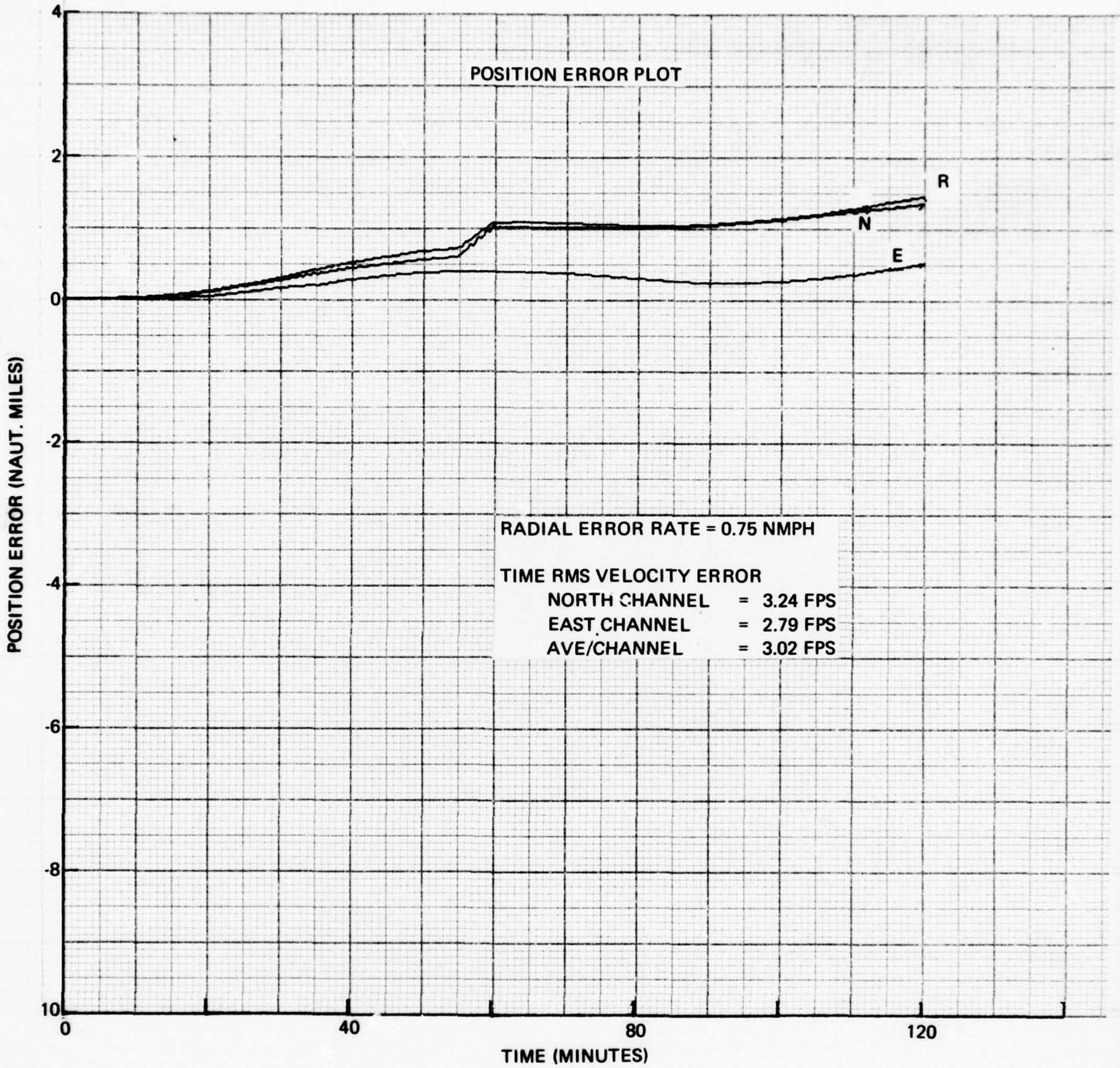
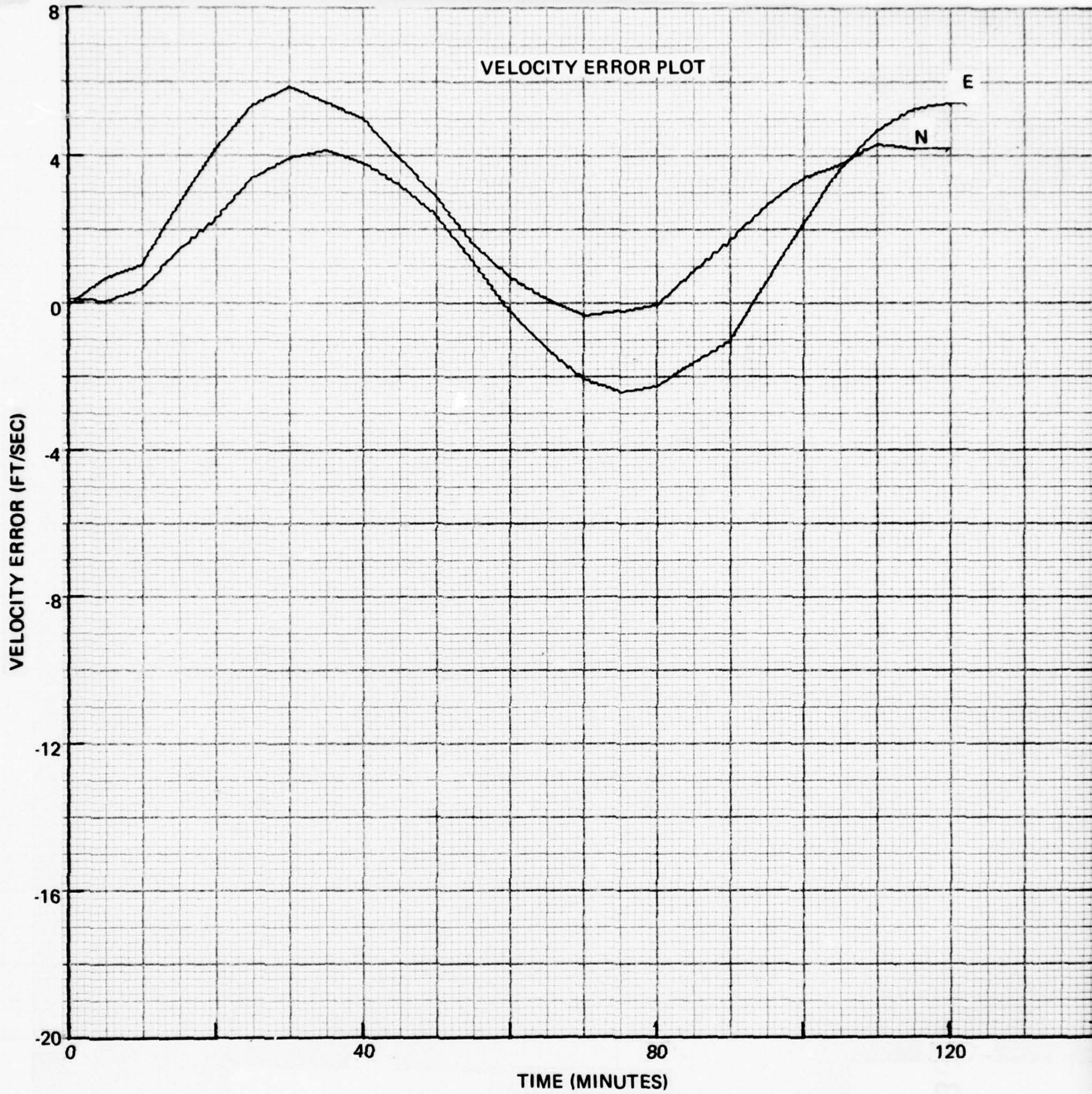


Figure N-19. EPM 1 NAV Run 0214772235, 90 Deg Heading

1



VELOCITY ERROR PLOT
E
N
VELOCITY ERROR (FT/SEC)
8
4
0
-4
-8
-12
-16
-20
0
40
80
120
TIME (MINUTES)

2

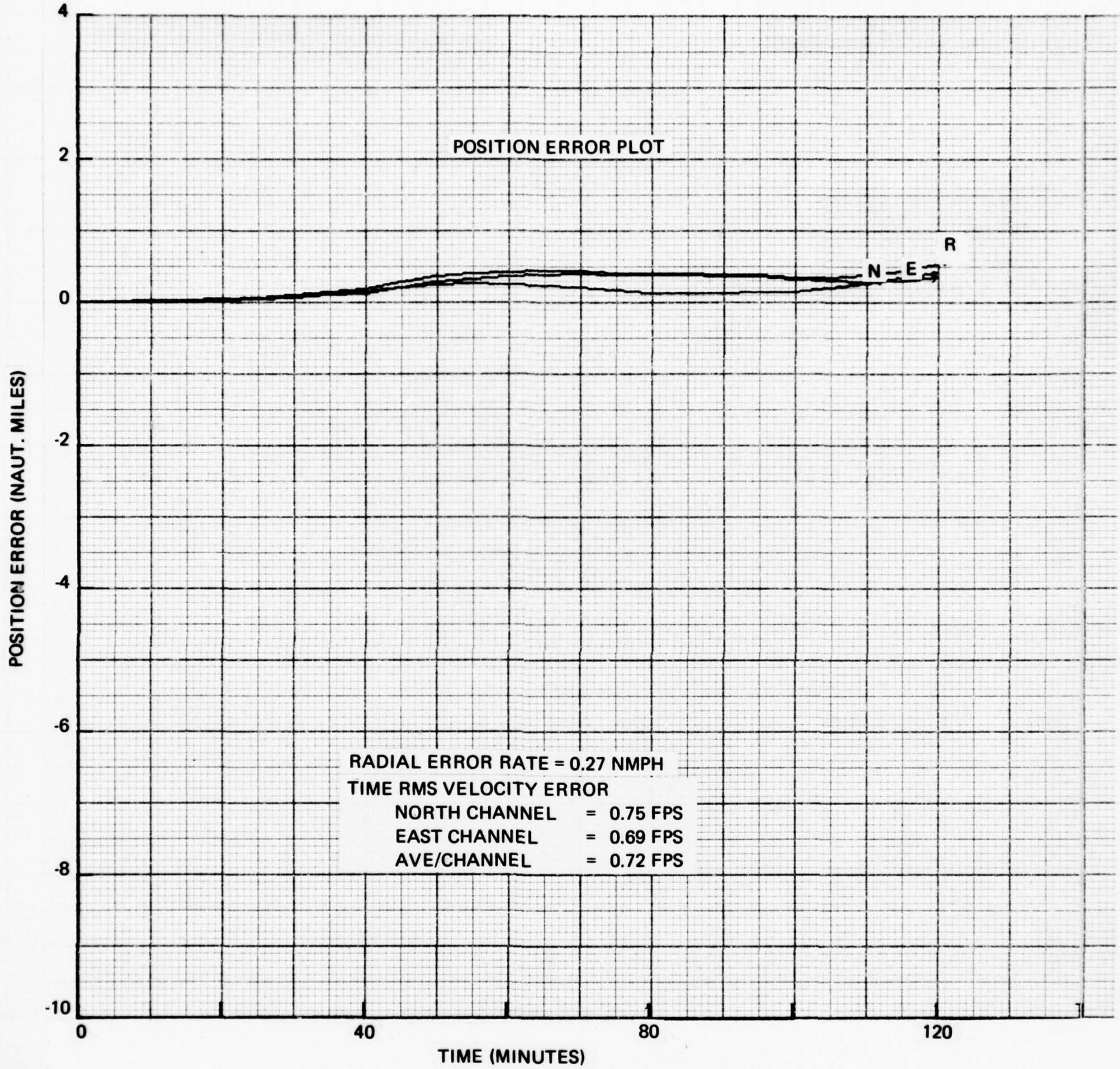
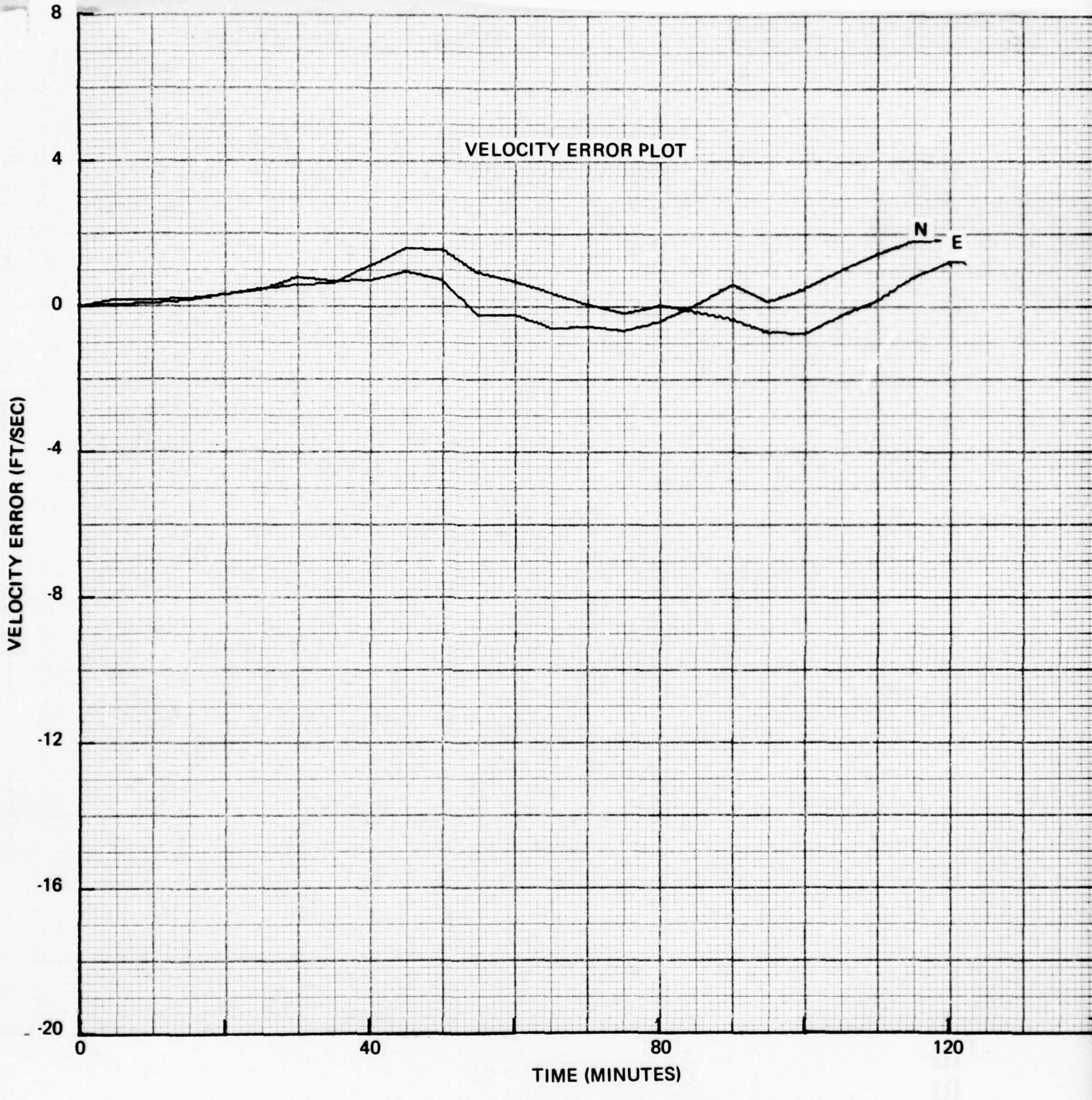


Figure N-20. EPM 1 NAV Run 0215770056, 0 Deg Heading

1


VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
8
4
0
-4
-8
-12
-16
-20
0
40
80
120
TIME (MINUTES)
N
E

2

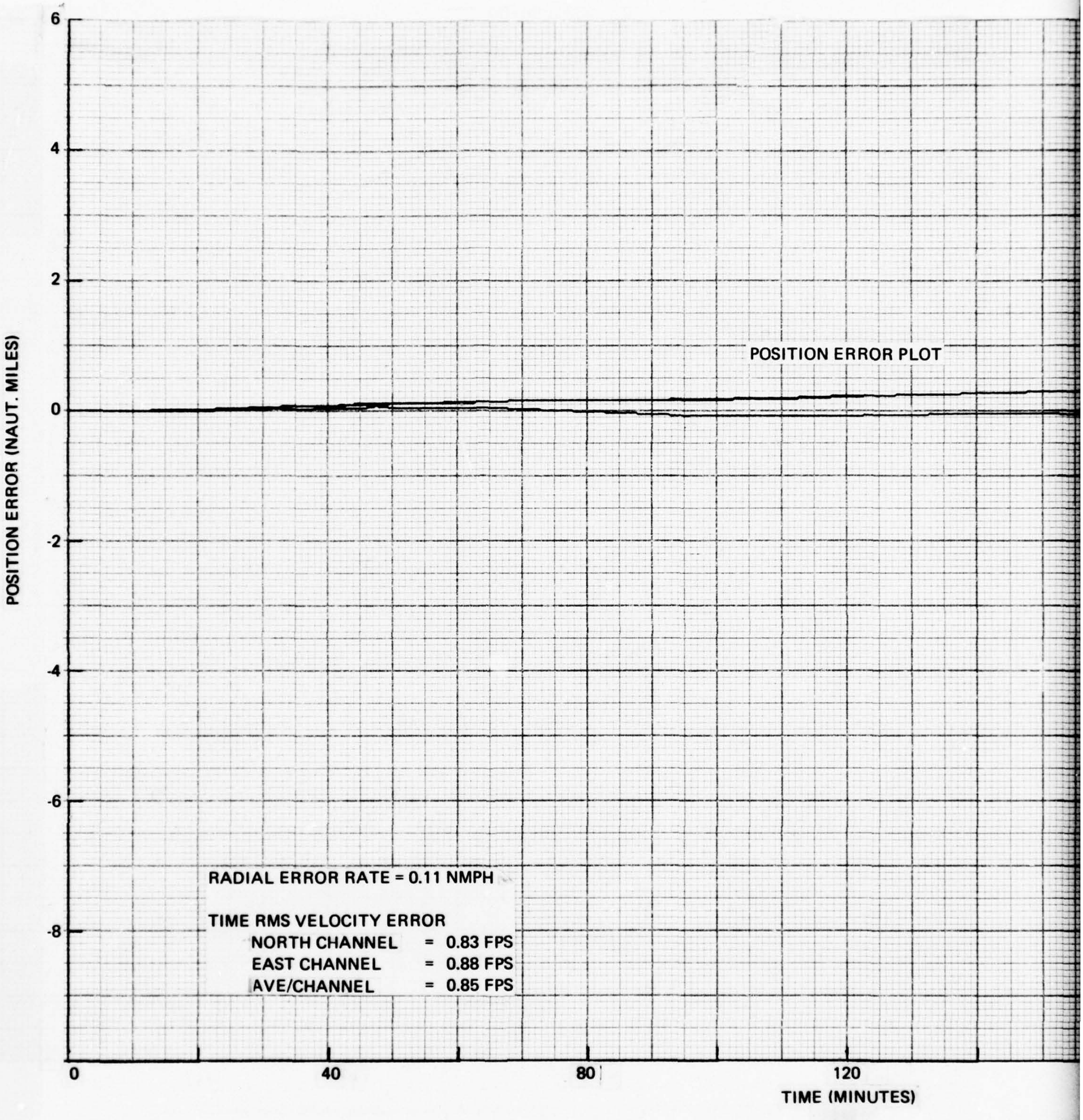
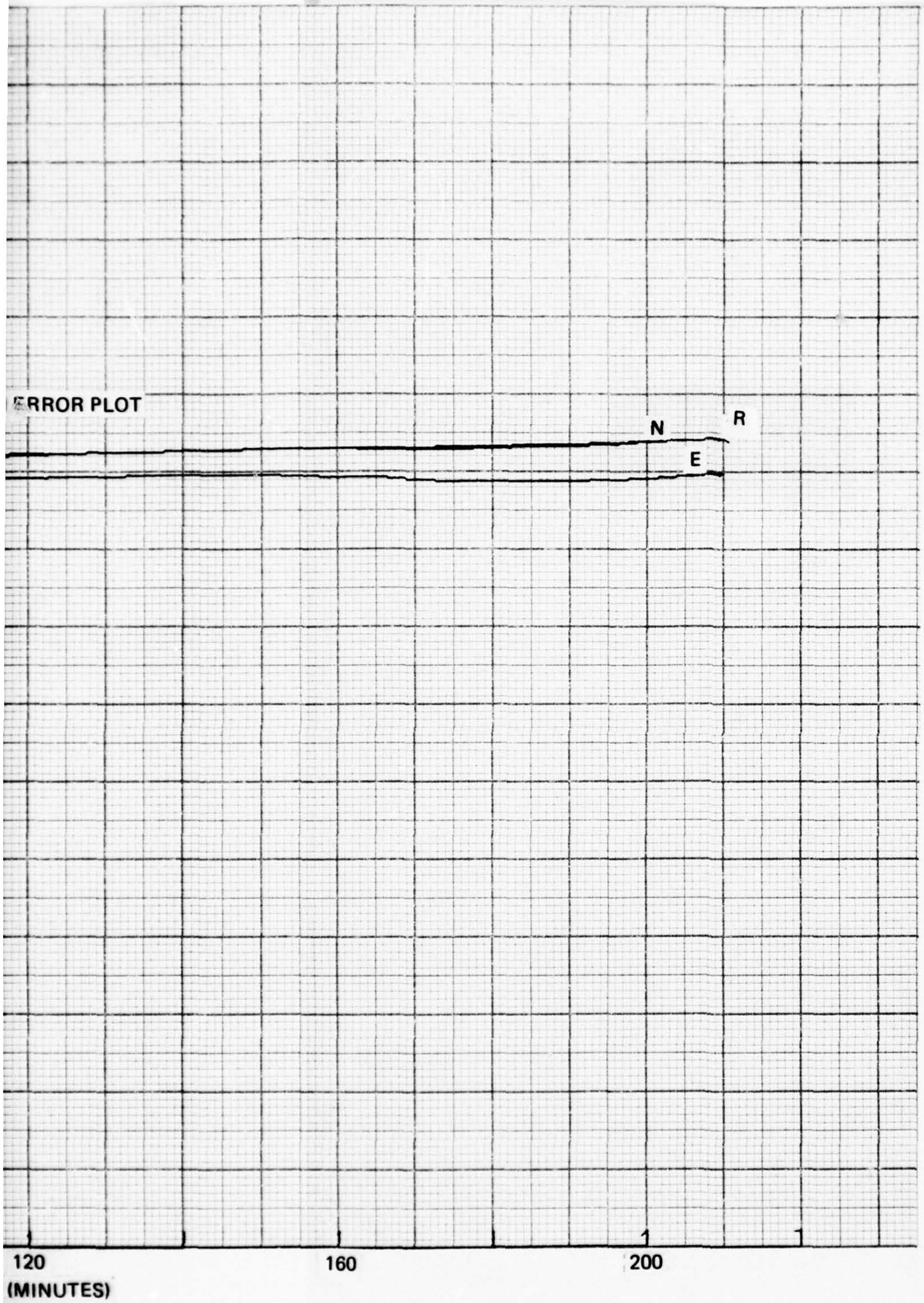
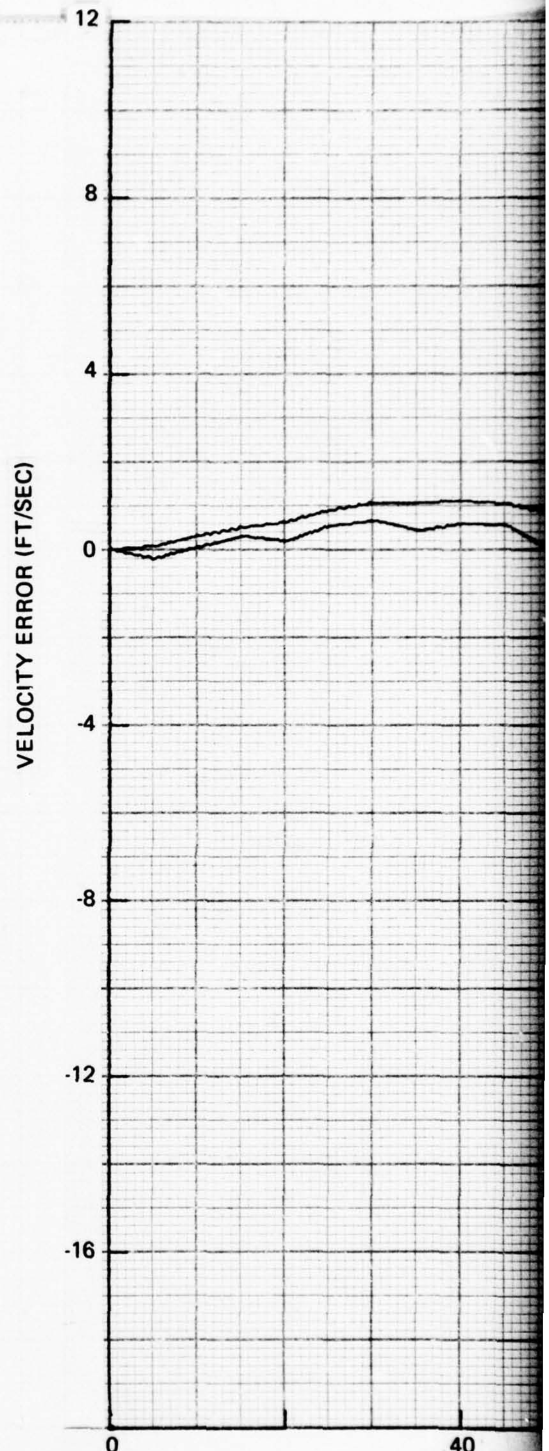


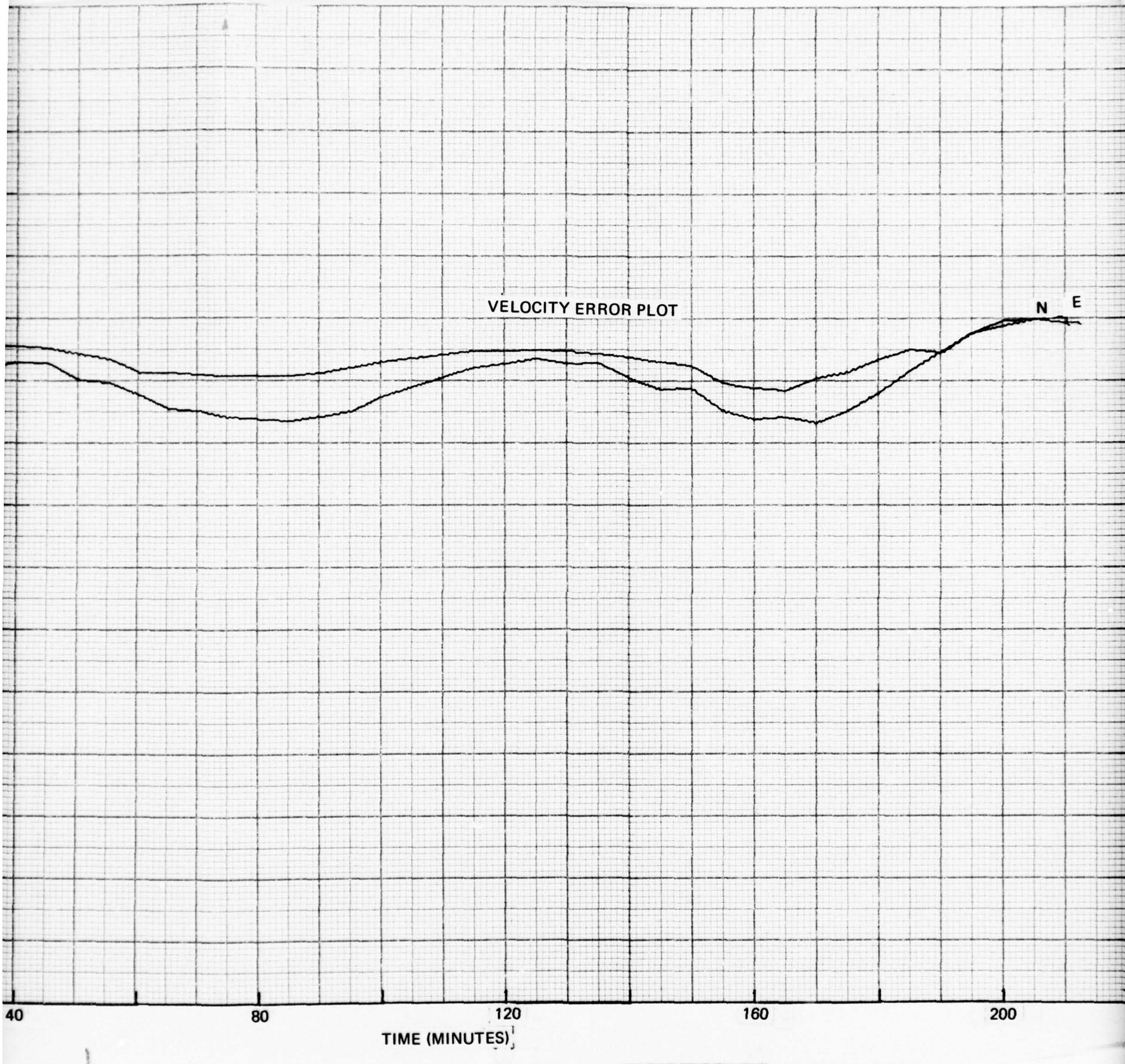
Figure N-21. EPM 1 NAV Run 0216771820, 163 Deg Heading

1


ERROR PLOT
N
R
E
120
160
200
(MINUTES)


12
8
4
0
-4
-8
-12
-16
VELOCITY ERROR (FT/SEC)
0
40

2



3

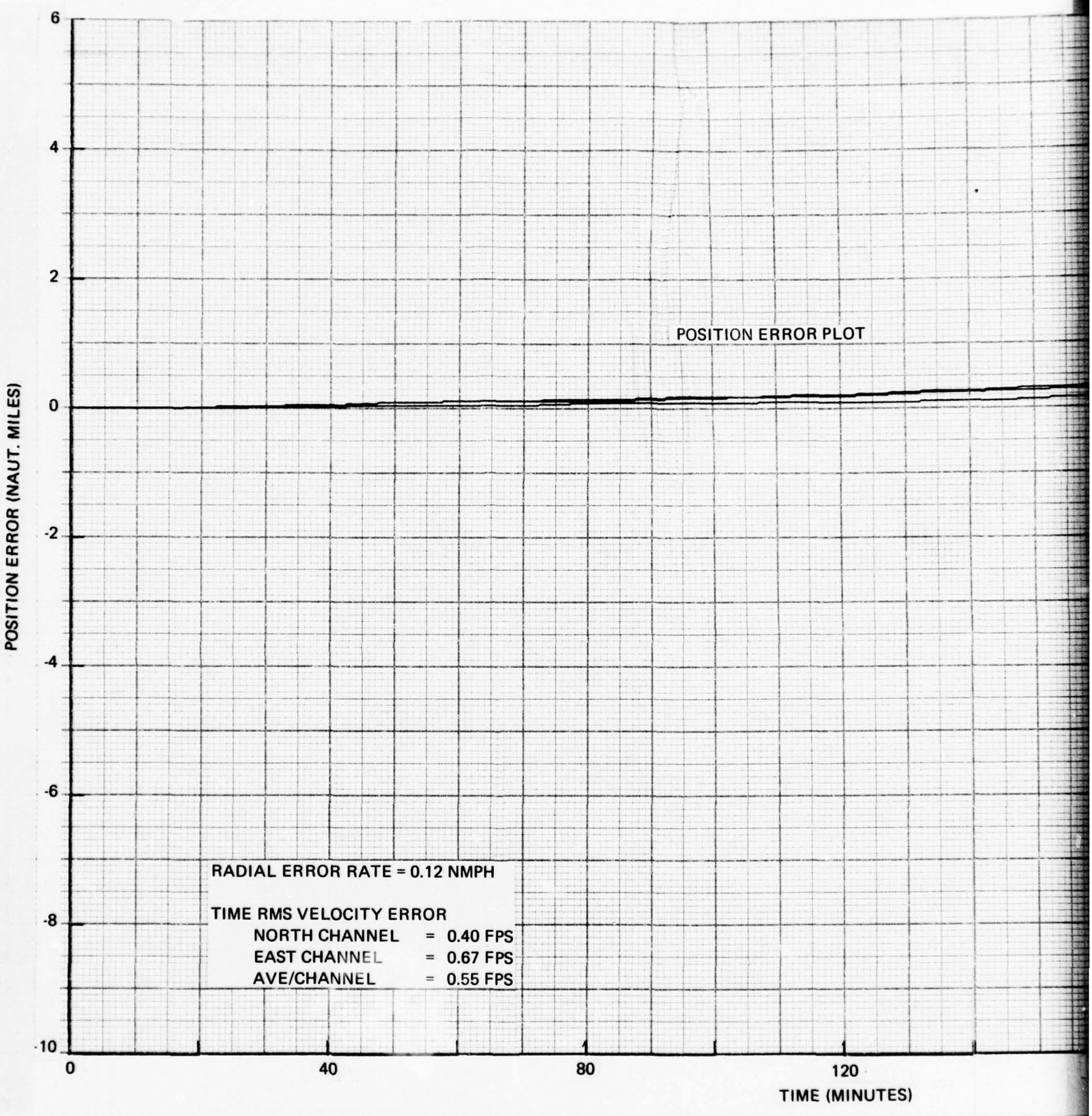
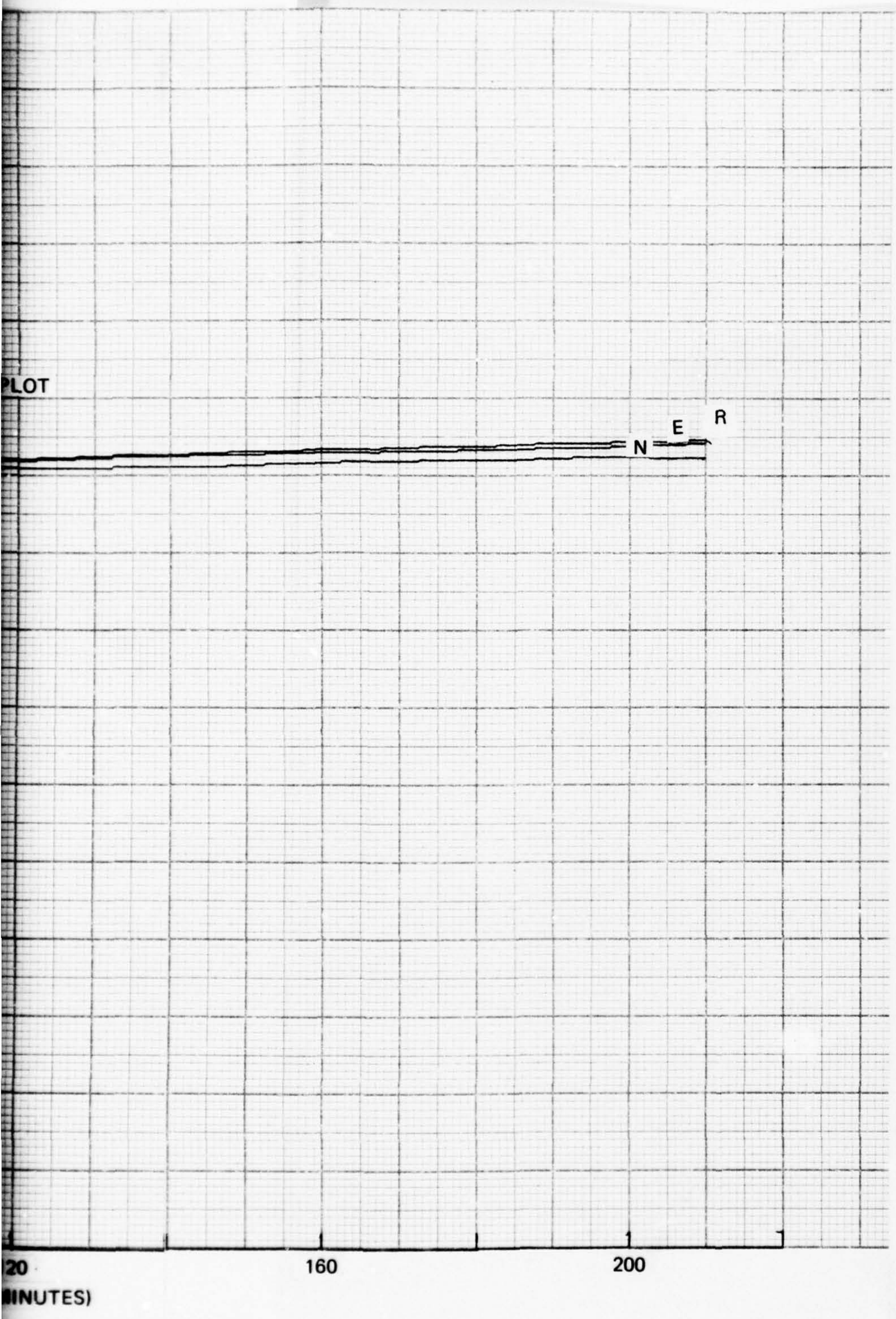
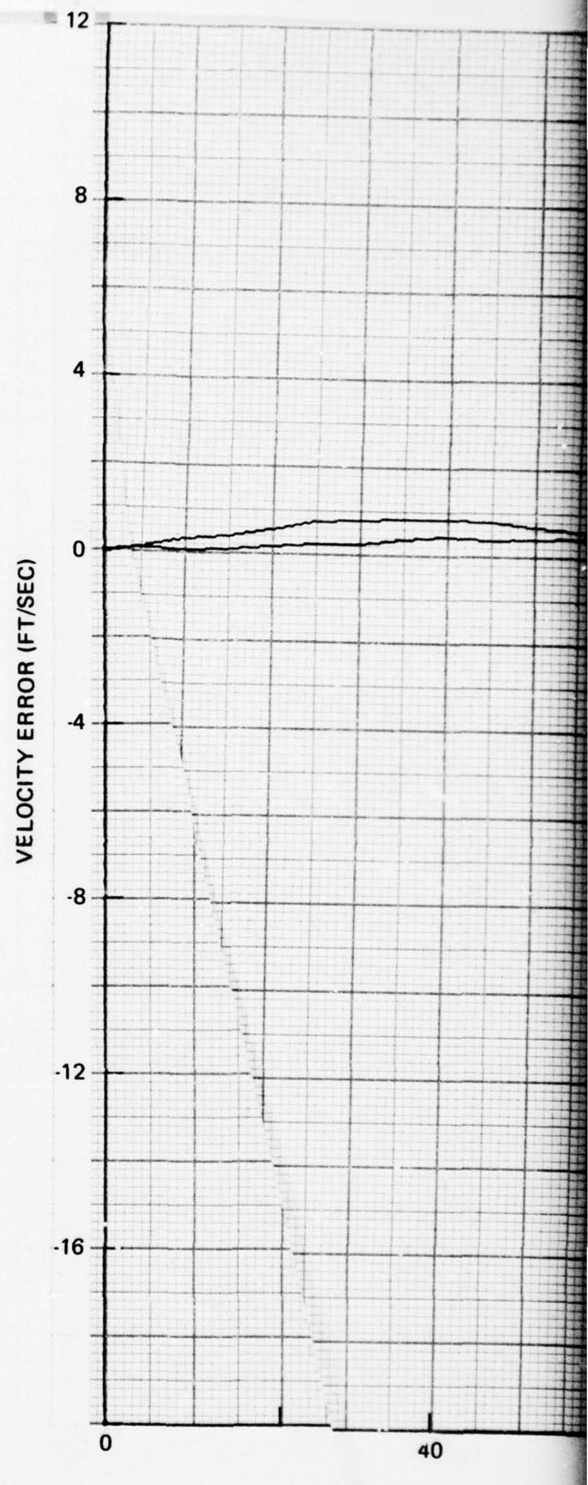


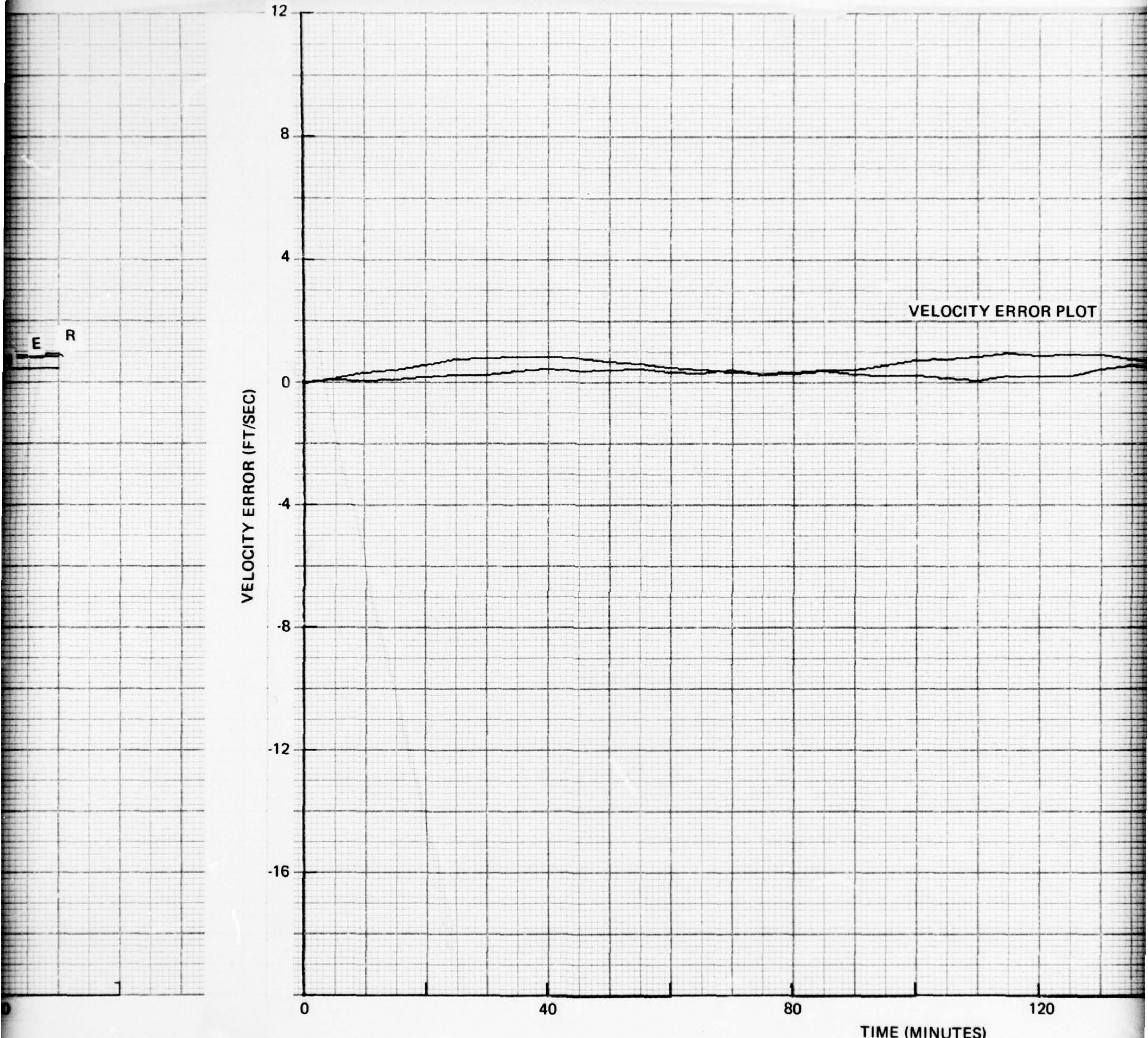
Figure N-22. EPM 1 NAV Run 0216772221, 161 Deg Heading

1


PLOT
N
E
R
20
160
200
INUTES)

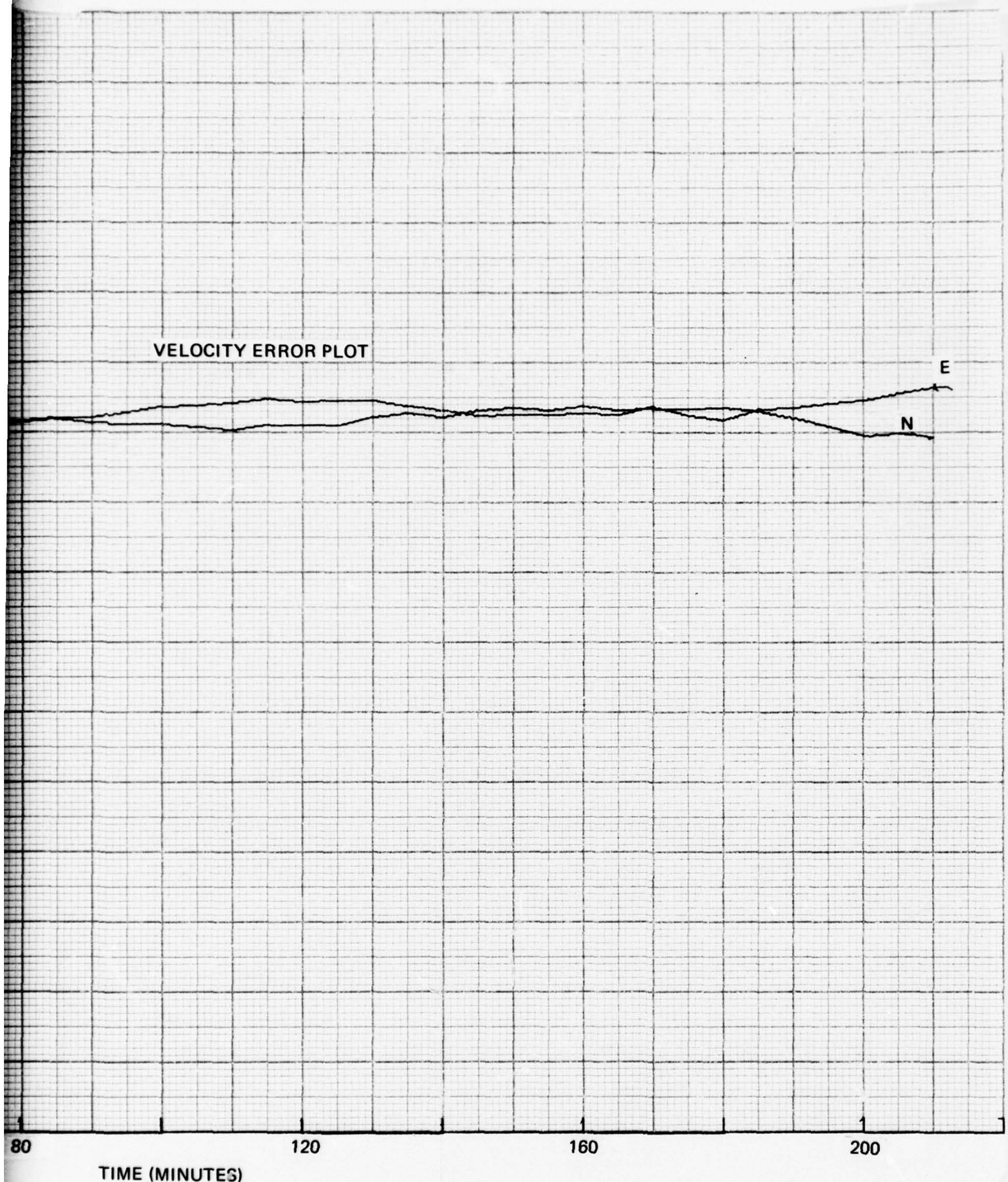

12
8
4
0
-4
-8
-12
-16
VELOCITY ERROR (FT/SEC)
0
40

2



VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
TIME (MINUTES)
12
8
4
0
-4
-8
-12
-16
0
40
80
120
E
R

2



3

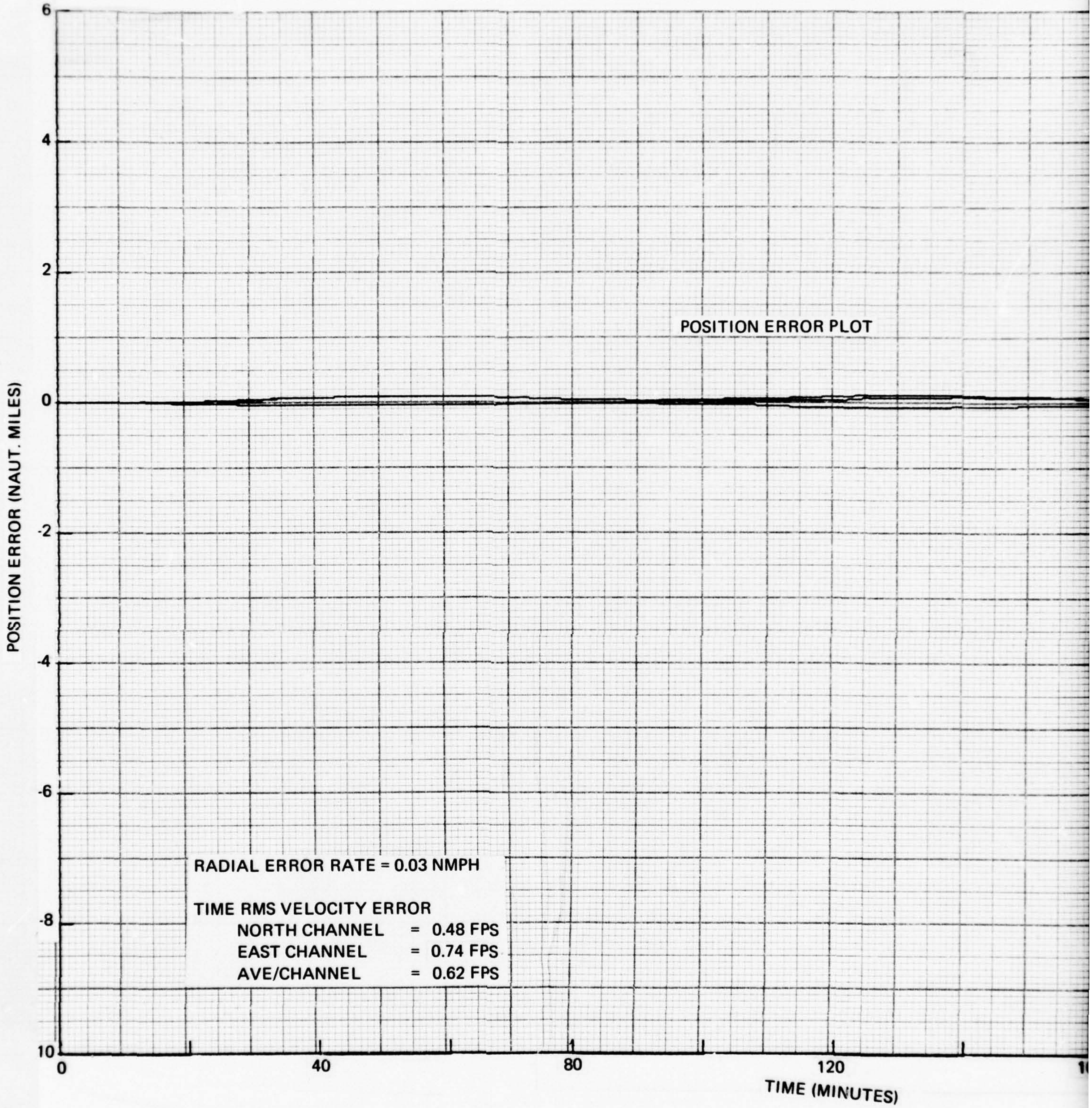
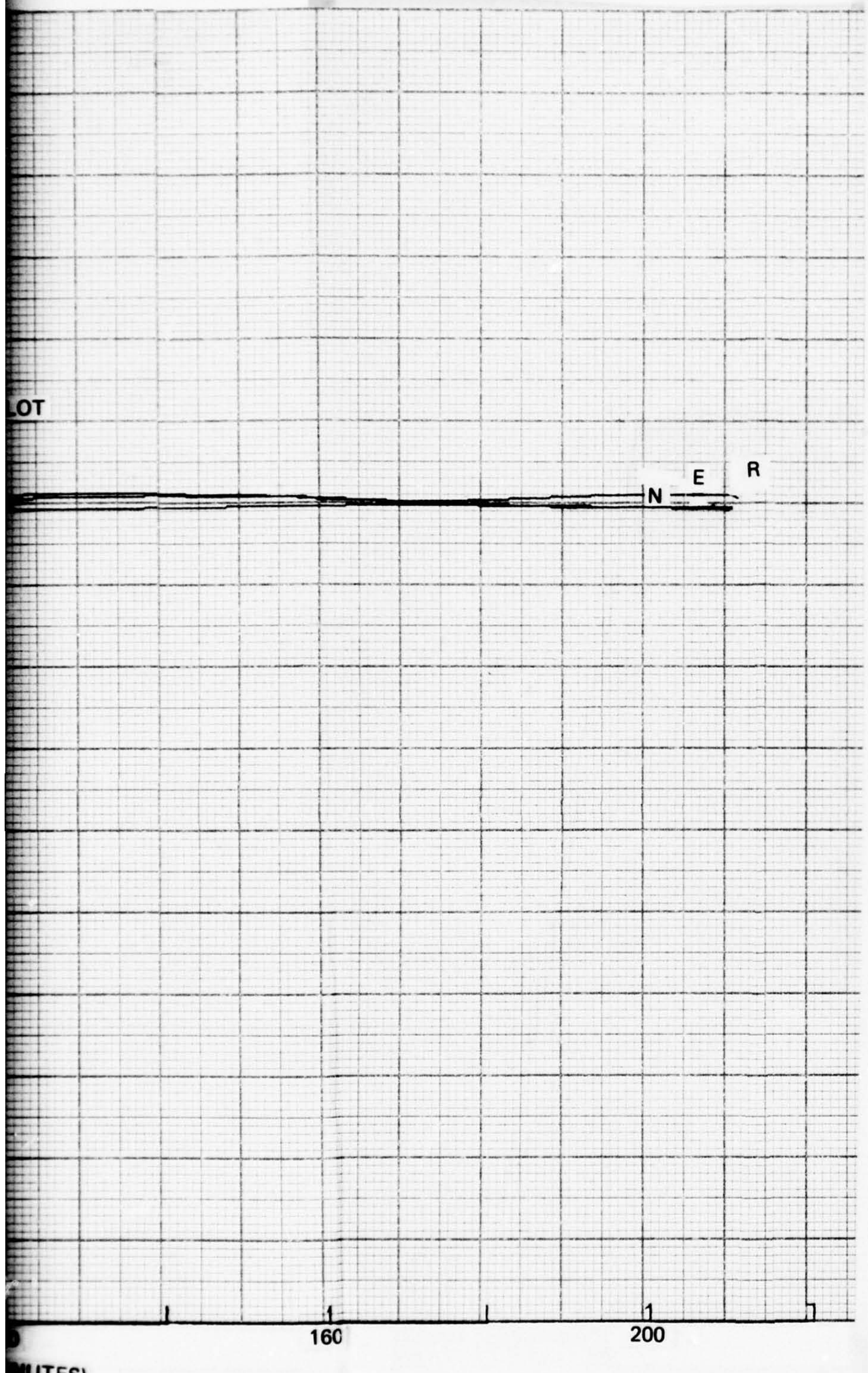
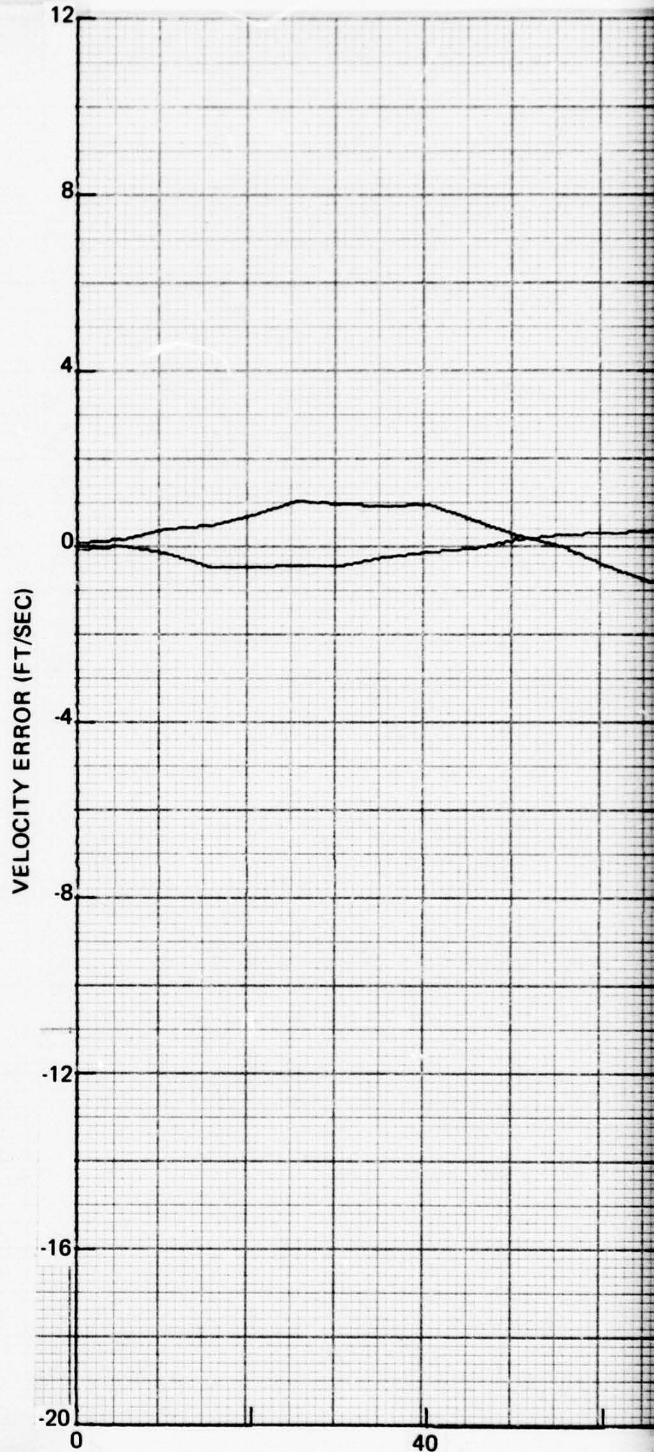


Figure N-23. EPM 1 NAV Run 0217770325, 161 Deg Heading

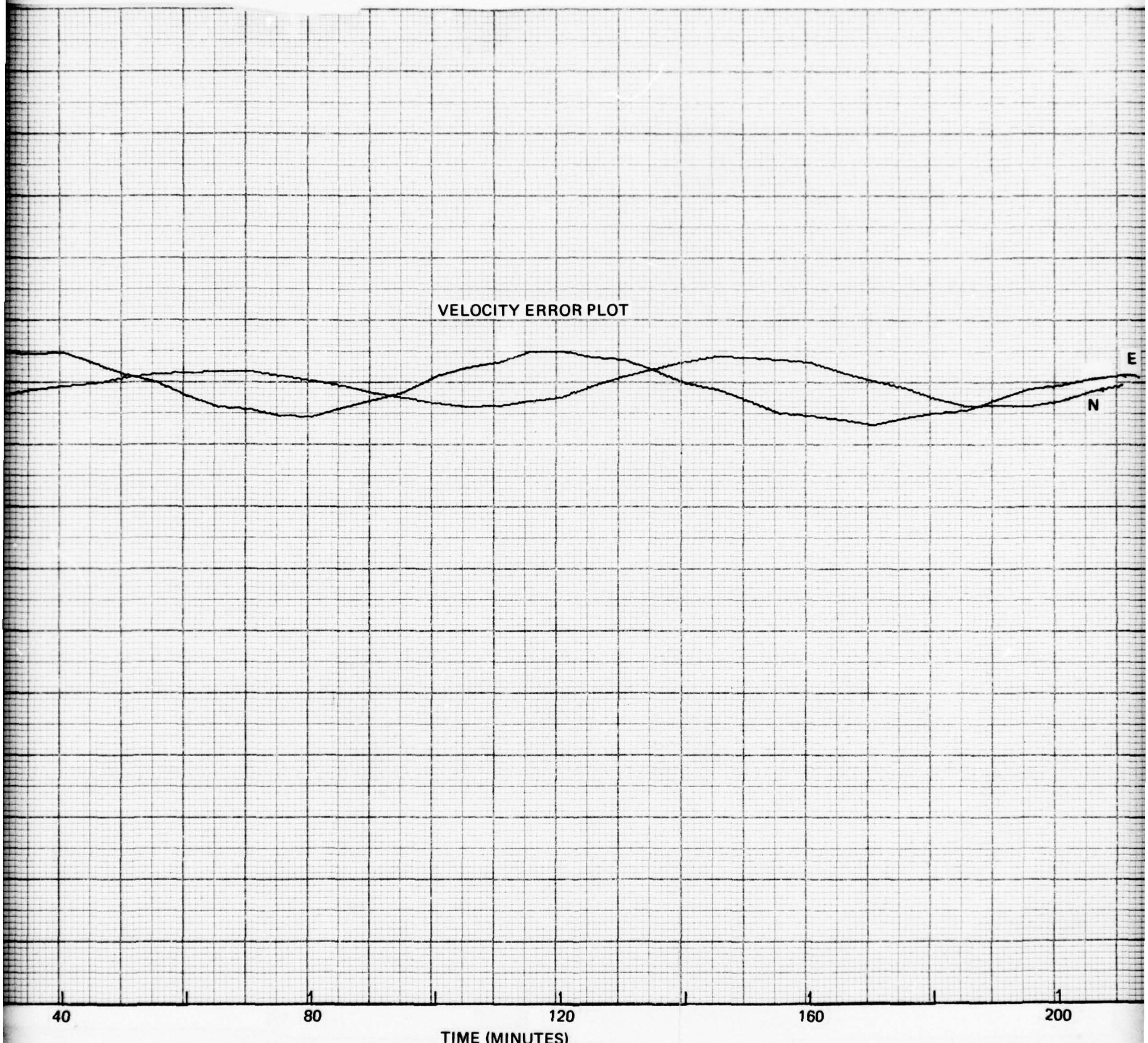
1


LOT
N
E
R
160
200
NUTES)


12
8
4
0
-4
-8
-12
-16
-20
0
40
VELOCITY ERROR (FT/SEC)

ng

2



3

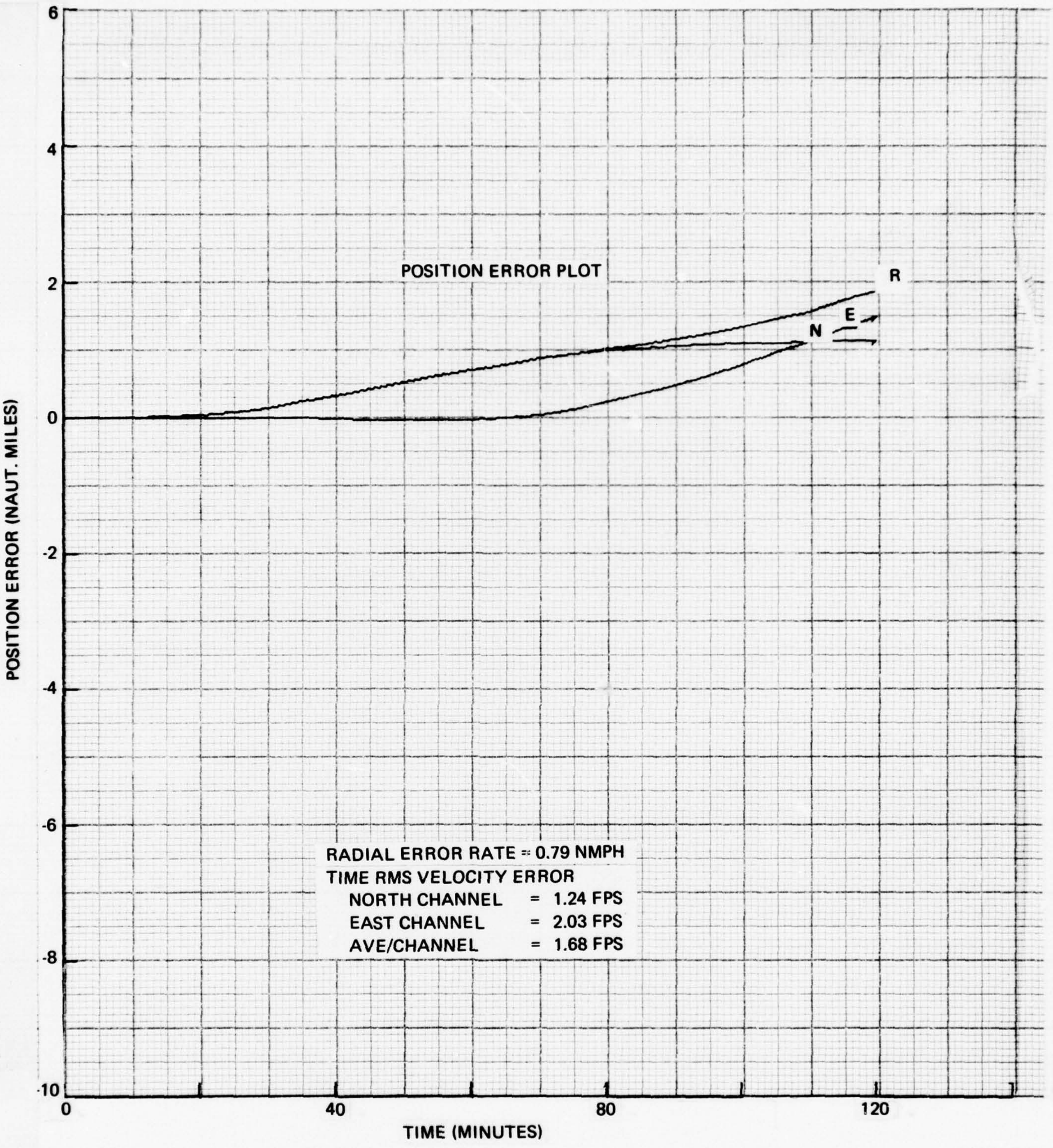
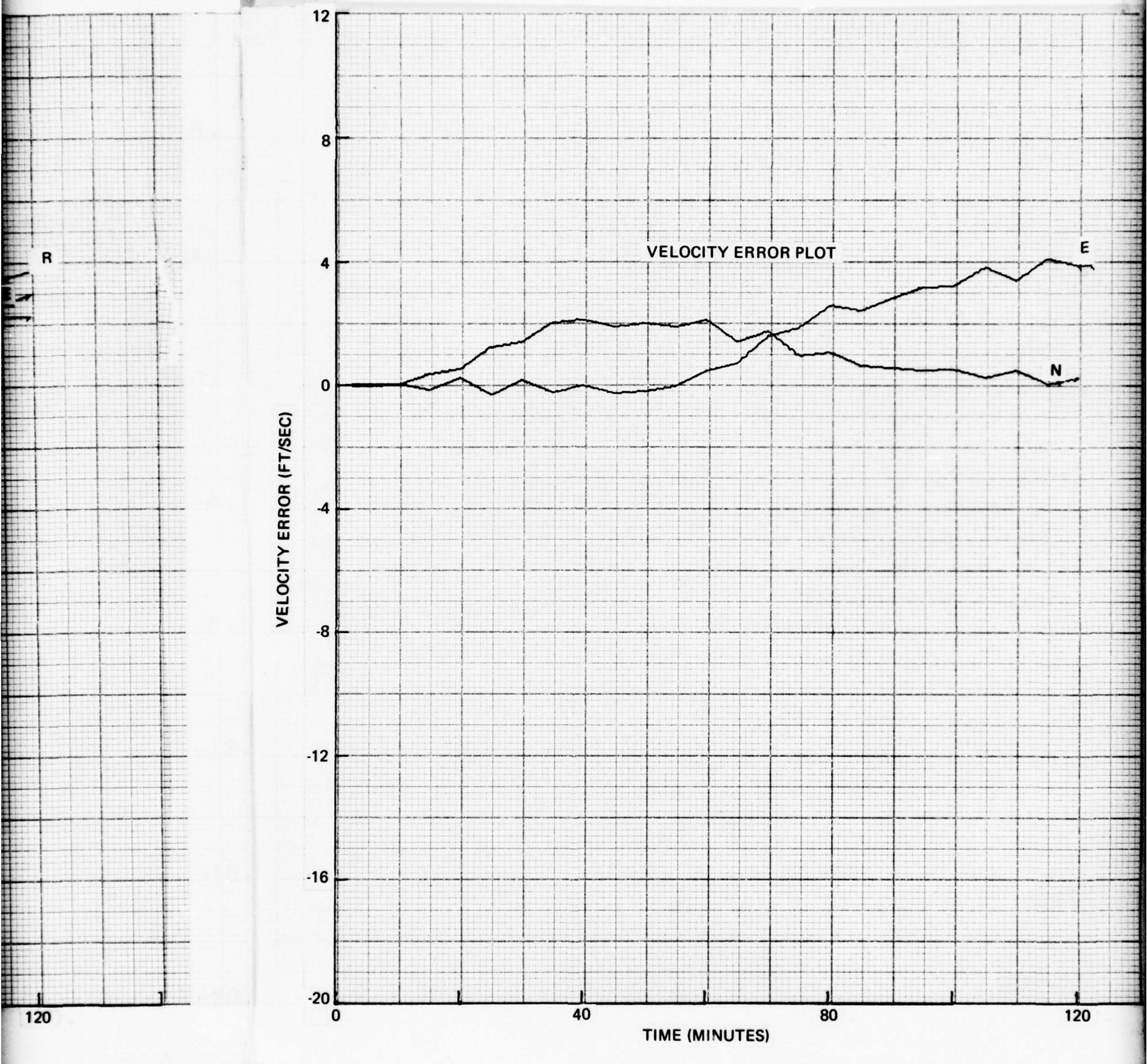


Figure N-24. EPM 2 NAV Run 0127772015, 0 Deg Heading

1



VELOCITY ERROR PLOT
E
N
VELOCITY ERROR (FT/SEC)
12
8
4
0
-4
-8
-12
-16
-20
0
40
80
120
TIME (MINUTES)

2

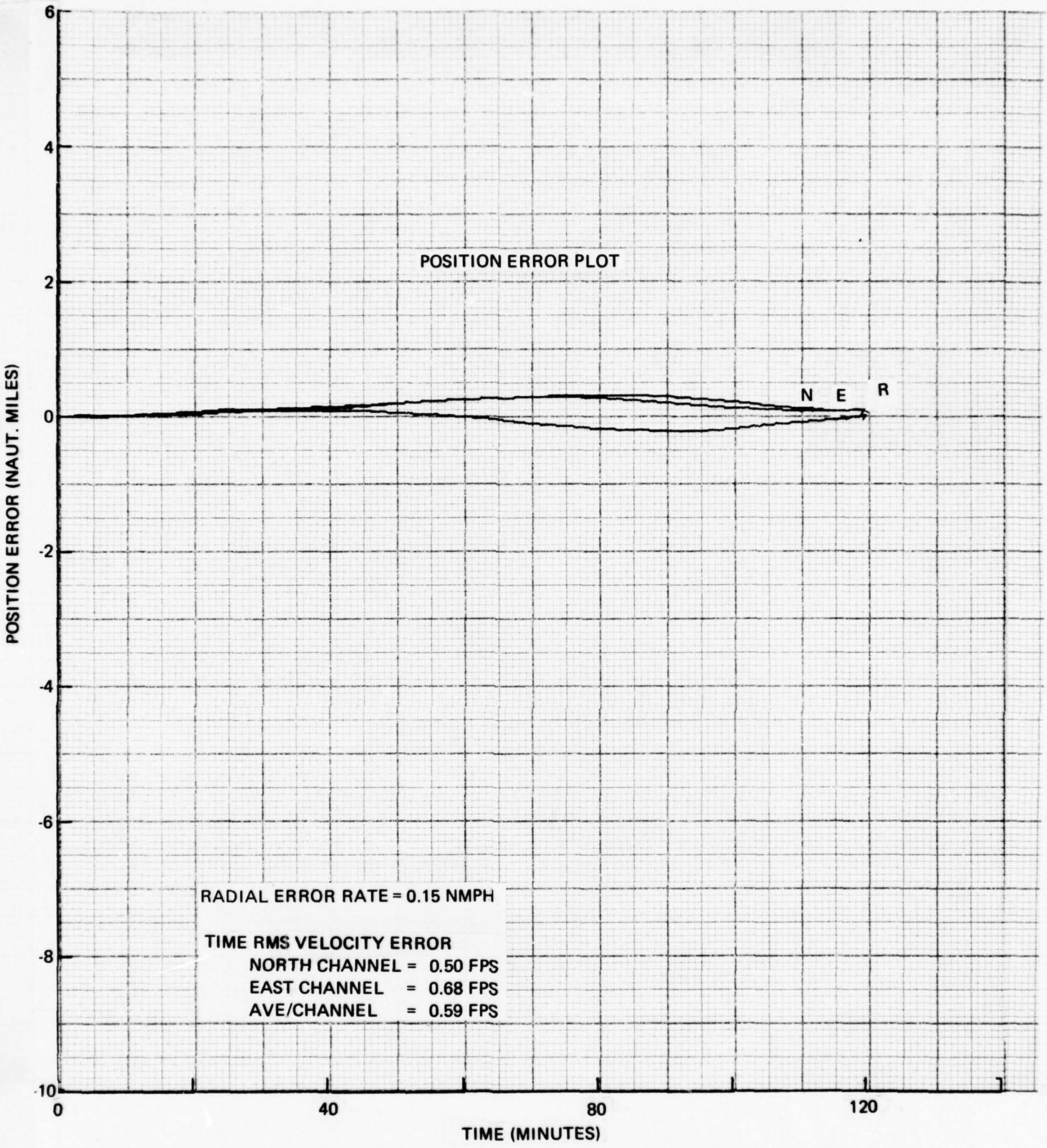
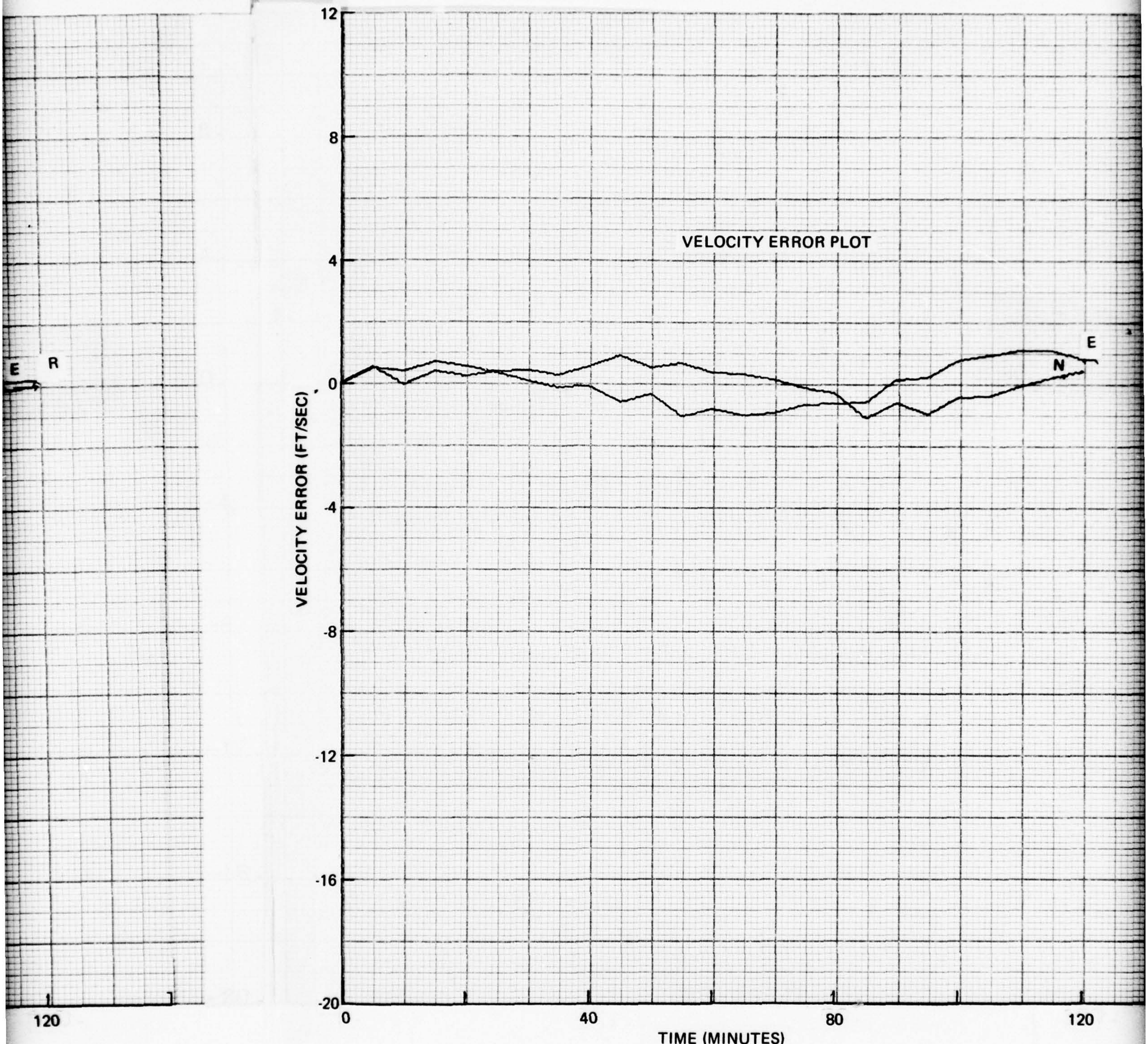


Figure N-25. EPM 2 NAV Run 0128770615, 90 Deg Heading

1


VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
TIME (MINUTES)
12
8
4
0
-4
-8
-12
-16
-20
0
40
80
120
E
N
E
R
120

ıg

2

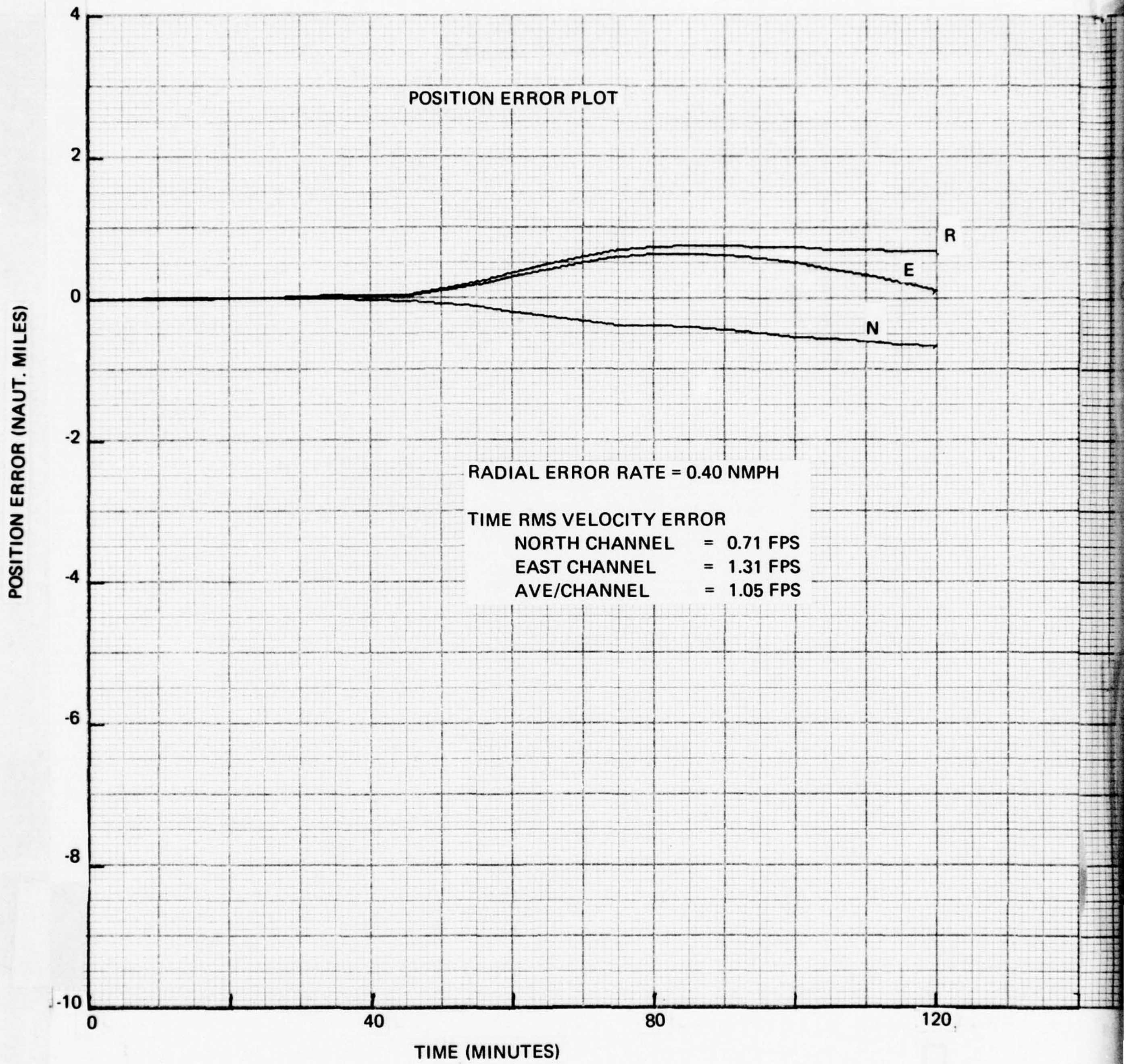
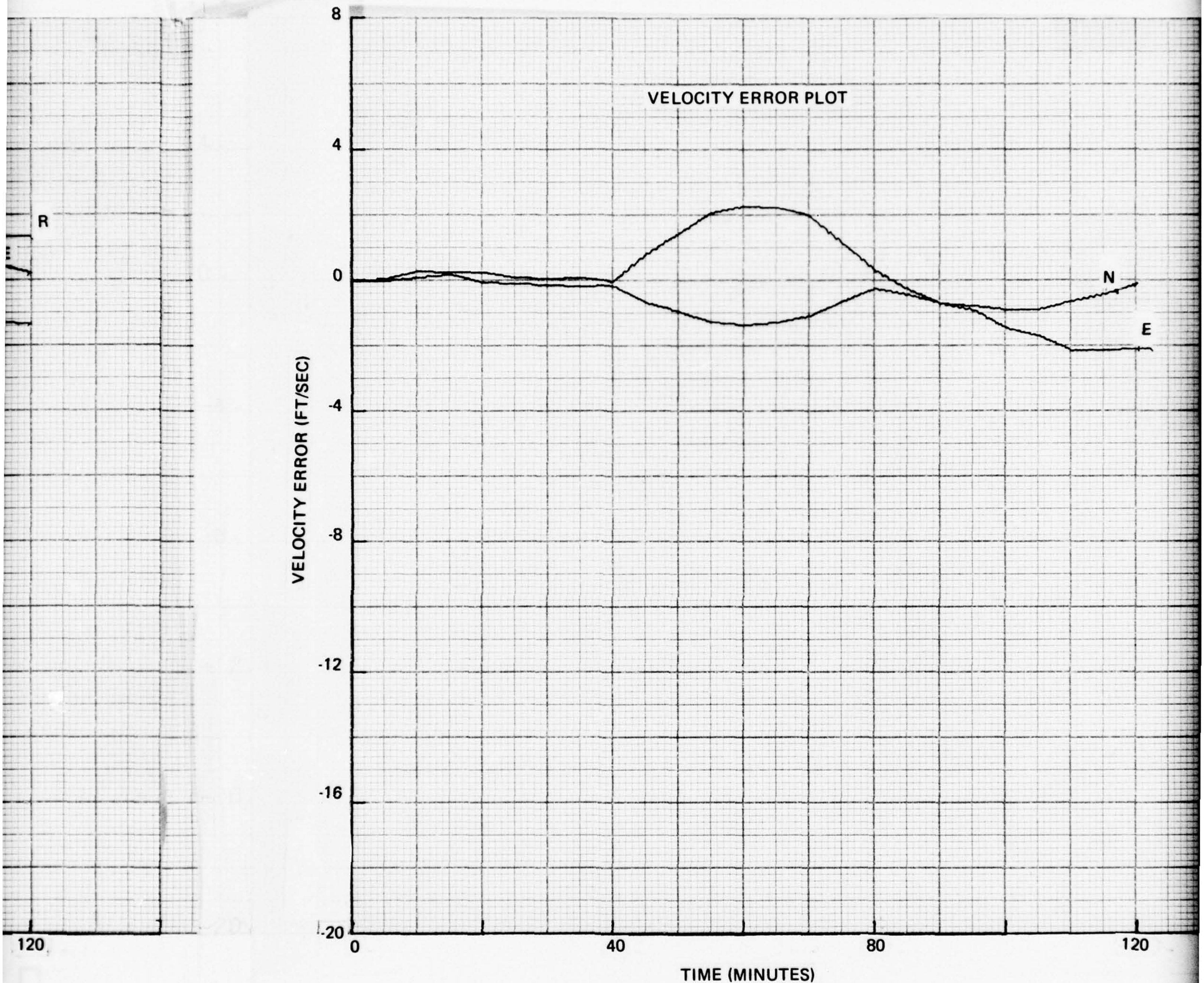


Figure N-34. EPM 2 NAV Run 0215770033, 0 Deg Heading

1


VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
8
4
0
-4
-8
-12
-16
-20
N
E
0
40
80
120
TIME (MINUTES)
R
120

2

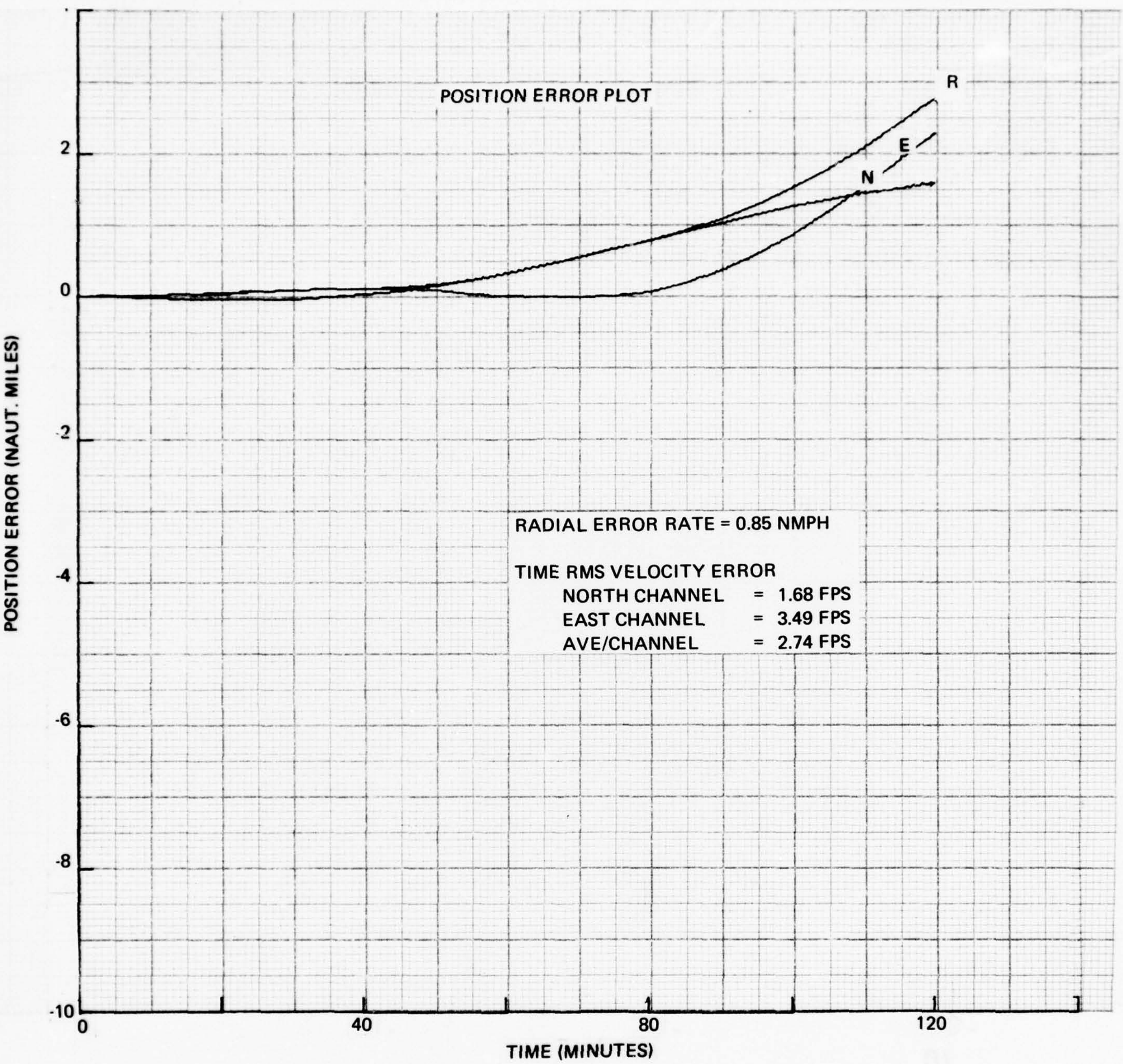
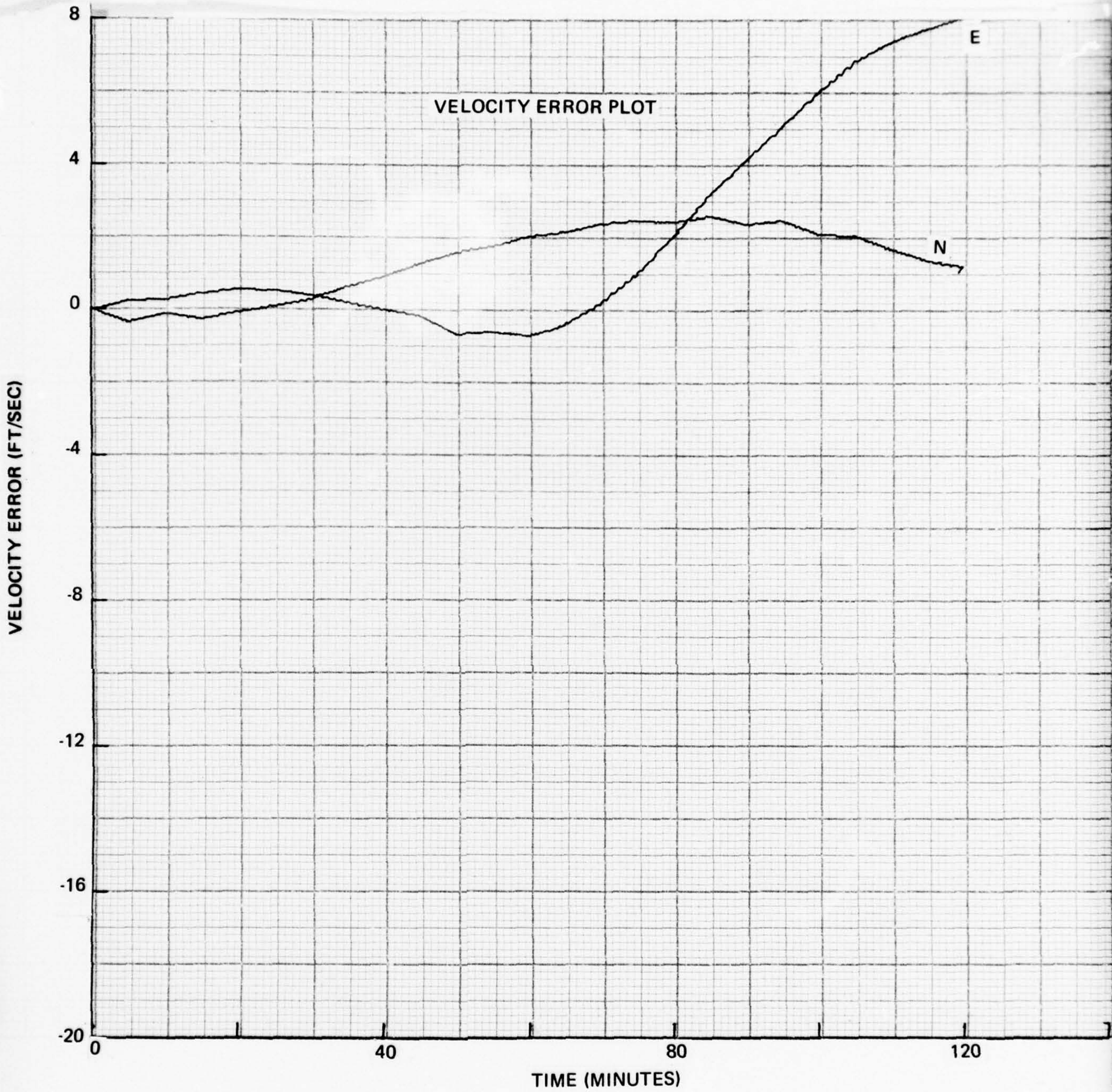
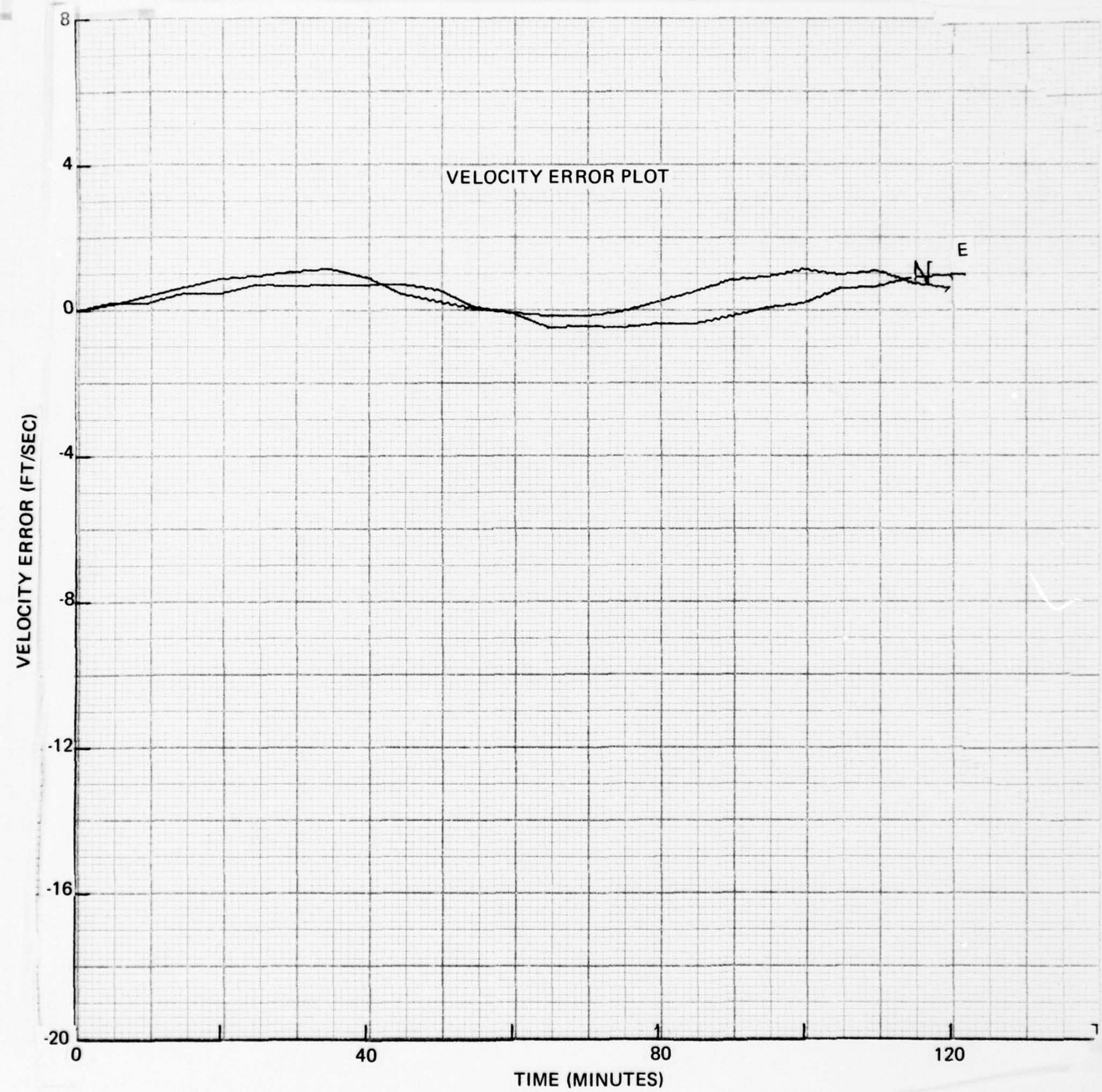


Figure 26. EPM 2 NAV Run 0131771945, 0 Deg Heading

1


VELOCITY ERROR PLOT
E
N
VELOCITY ERROR (FT/SEC)
8
4
0
-4
-8
-12
-16
-20
0
40
80
120
TIME (MINUTES)

2



VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
TIME (MINUTES)
E
N
8
4
0
-4
-8
-12
-16
-20
0
40
80
120

2

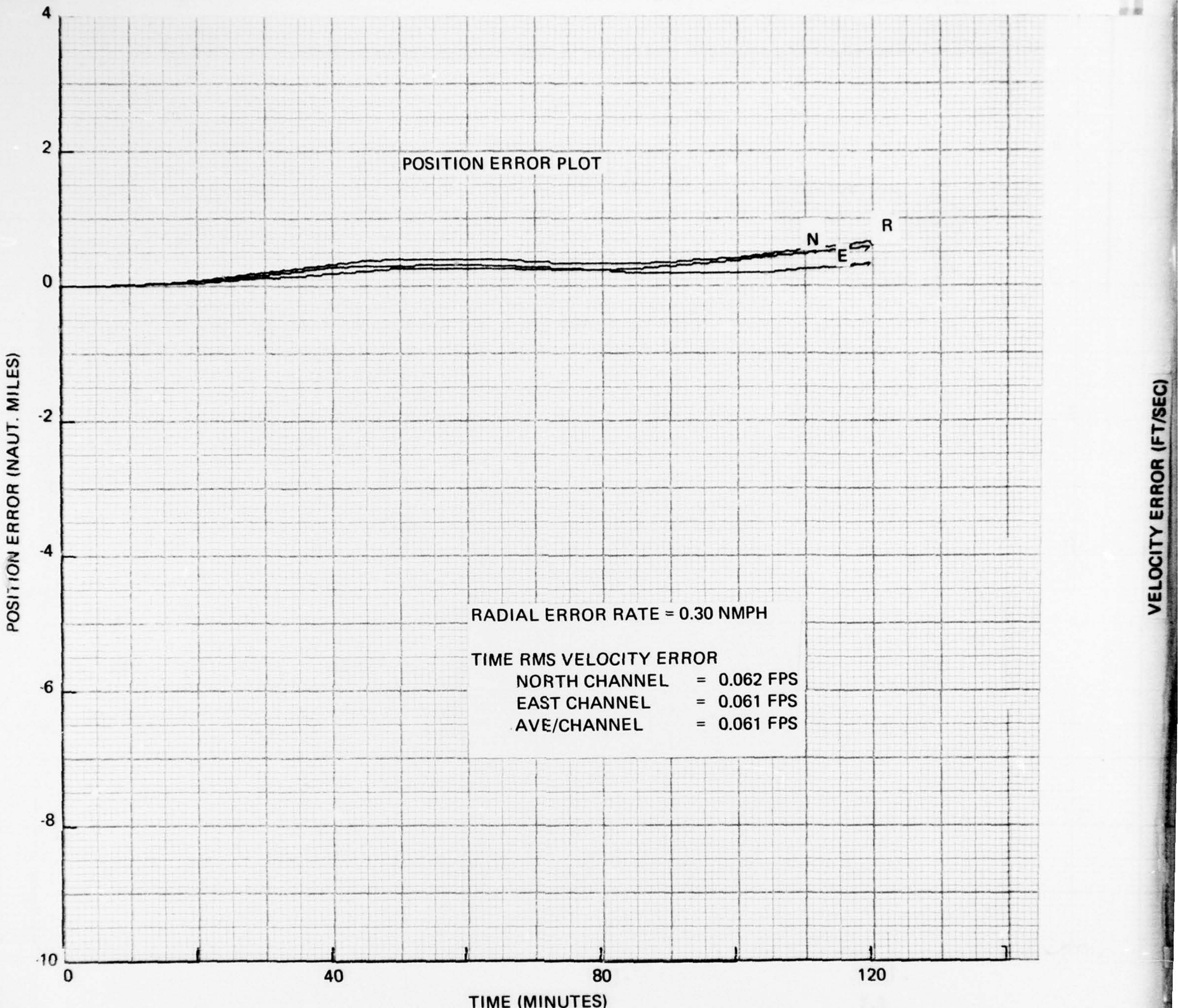
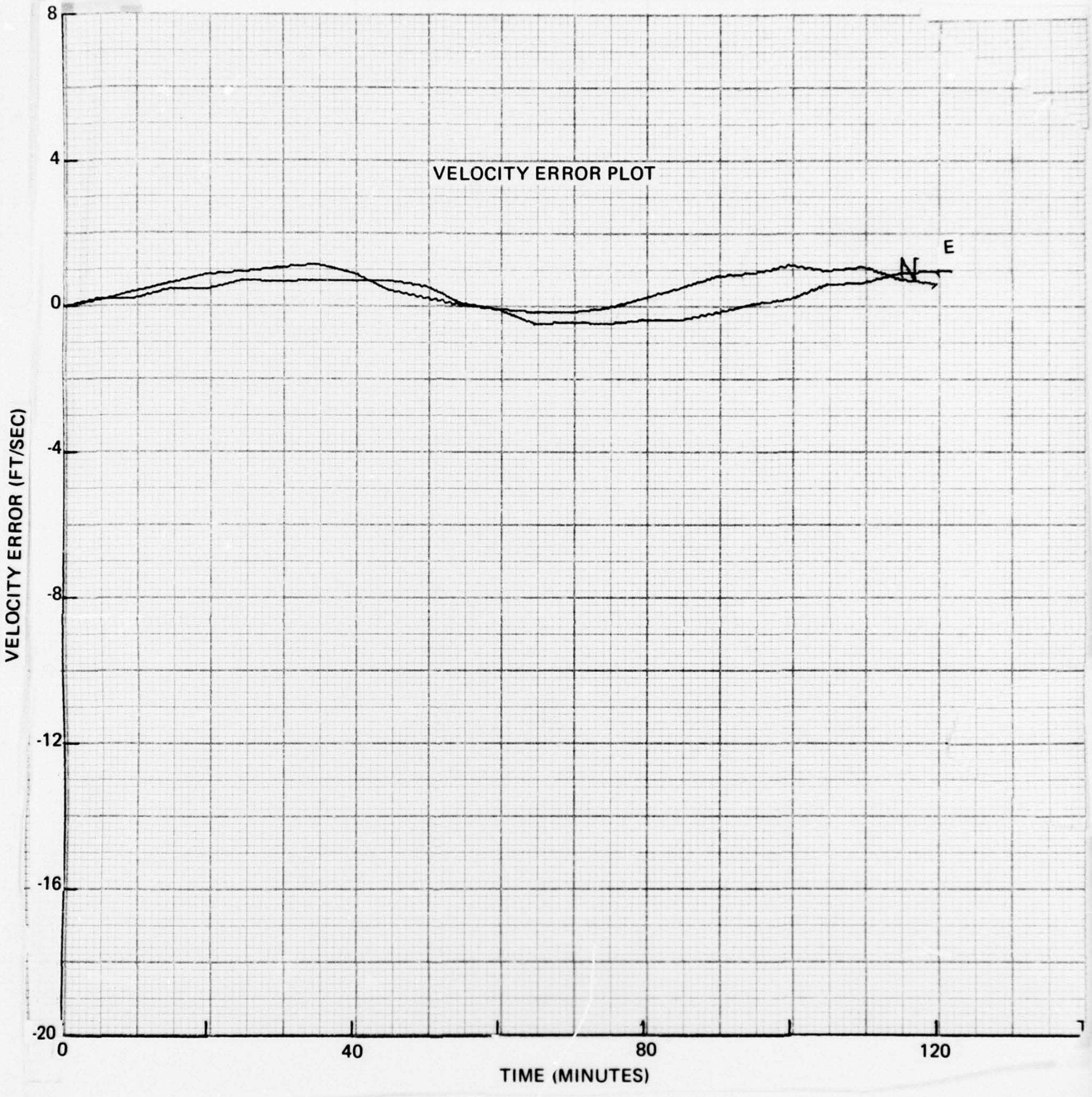


Figure N-27. EPM 2 NAV Run 0204772126, 0 Deg Heading

1


VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
8
4
0
-4
-8
-12
-16
-20
0
40
80
120
TIME (MINUTES)
E
N

2

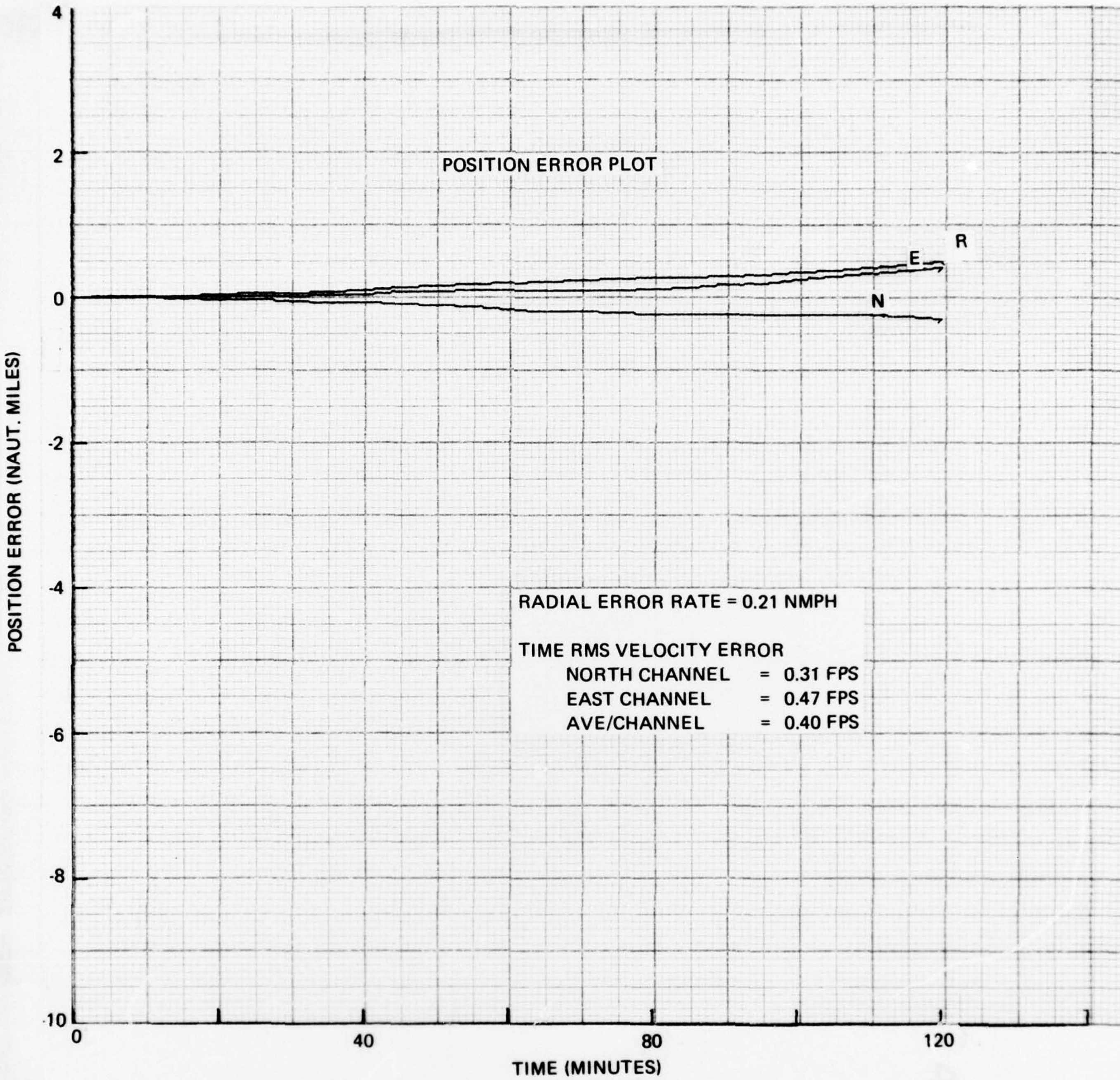
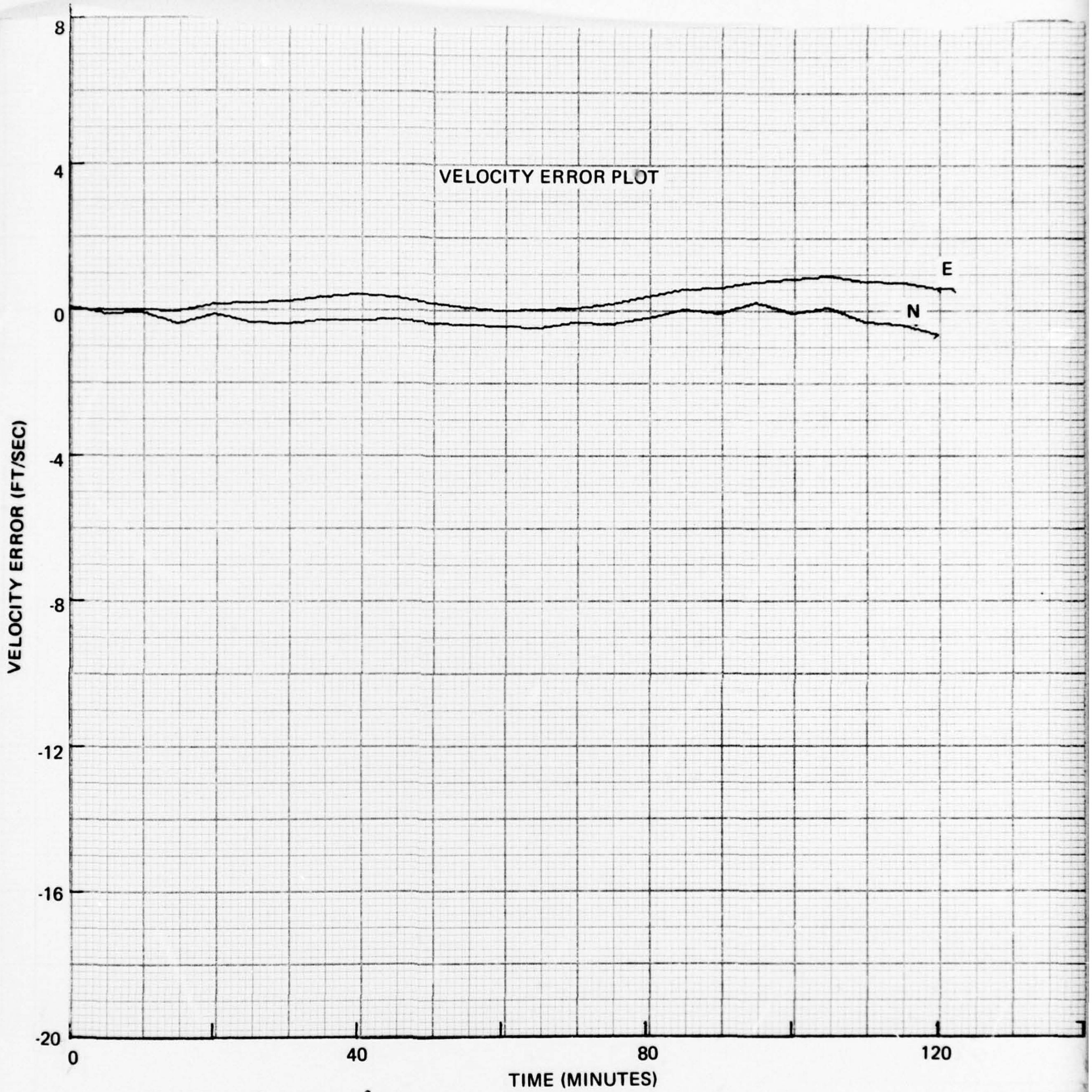


Figure N-28. EPM 2 NAV Run 0214770042, 0 Deg Heading

1


VELOCITY ERROR PLOT
E
N
VELOCITY ERROR (FT/SEC)
8
4
0
-4
-8
-12
-16
-20
0
40
80
120
TIME (MINUTES)

2

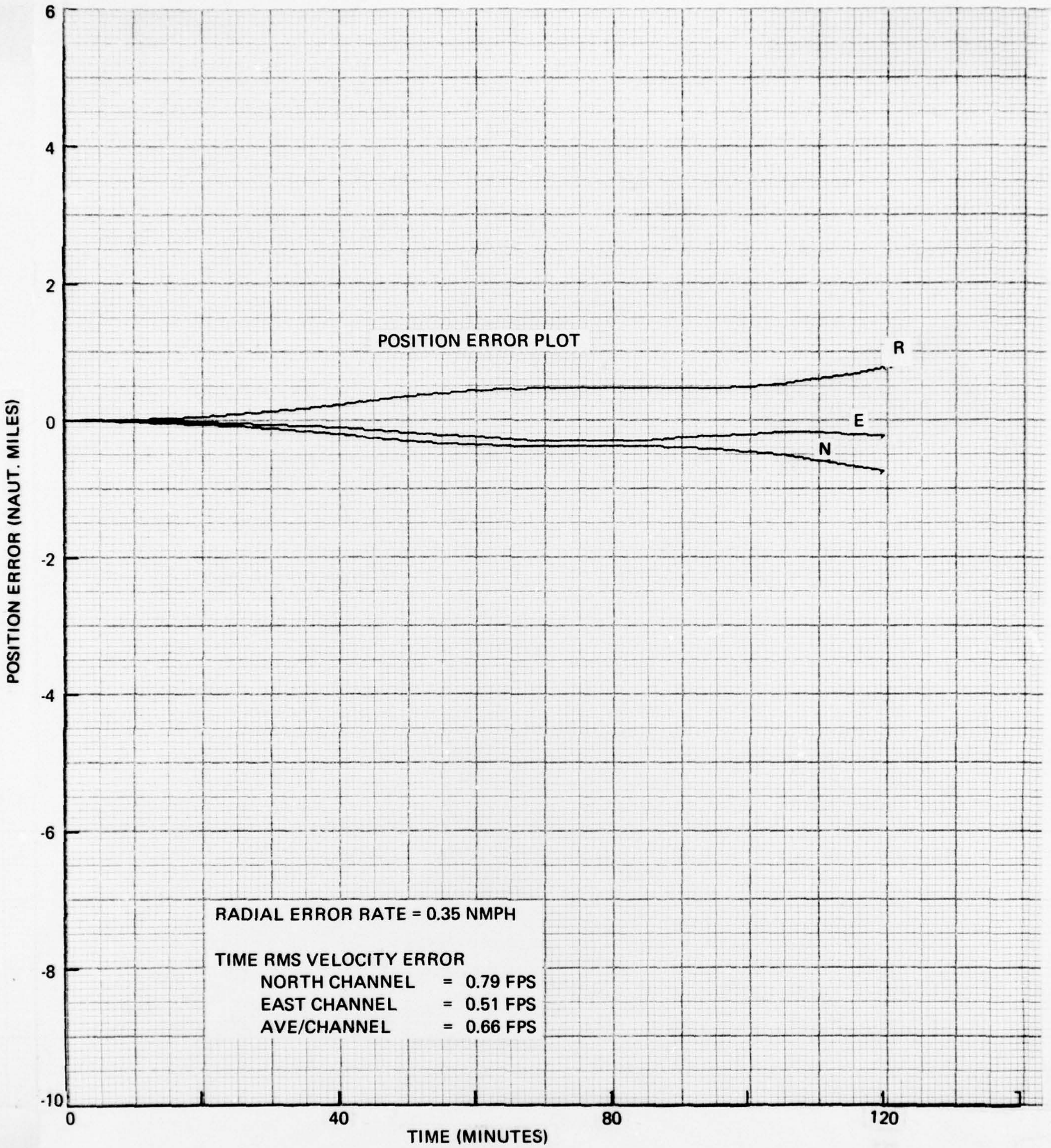
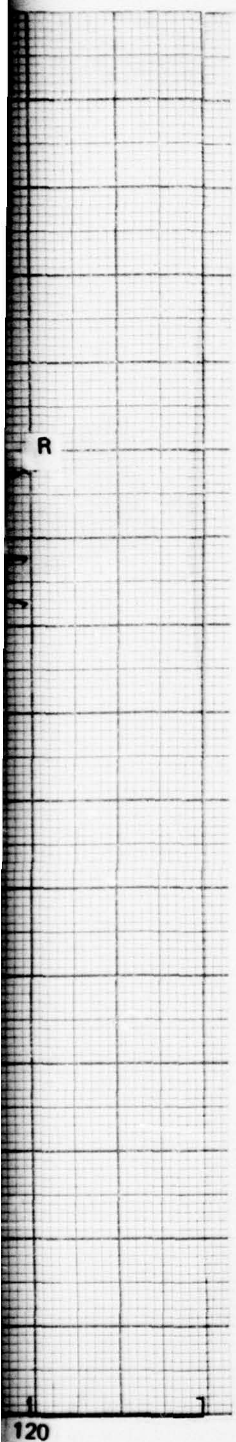
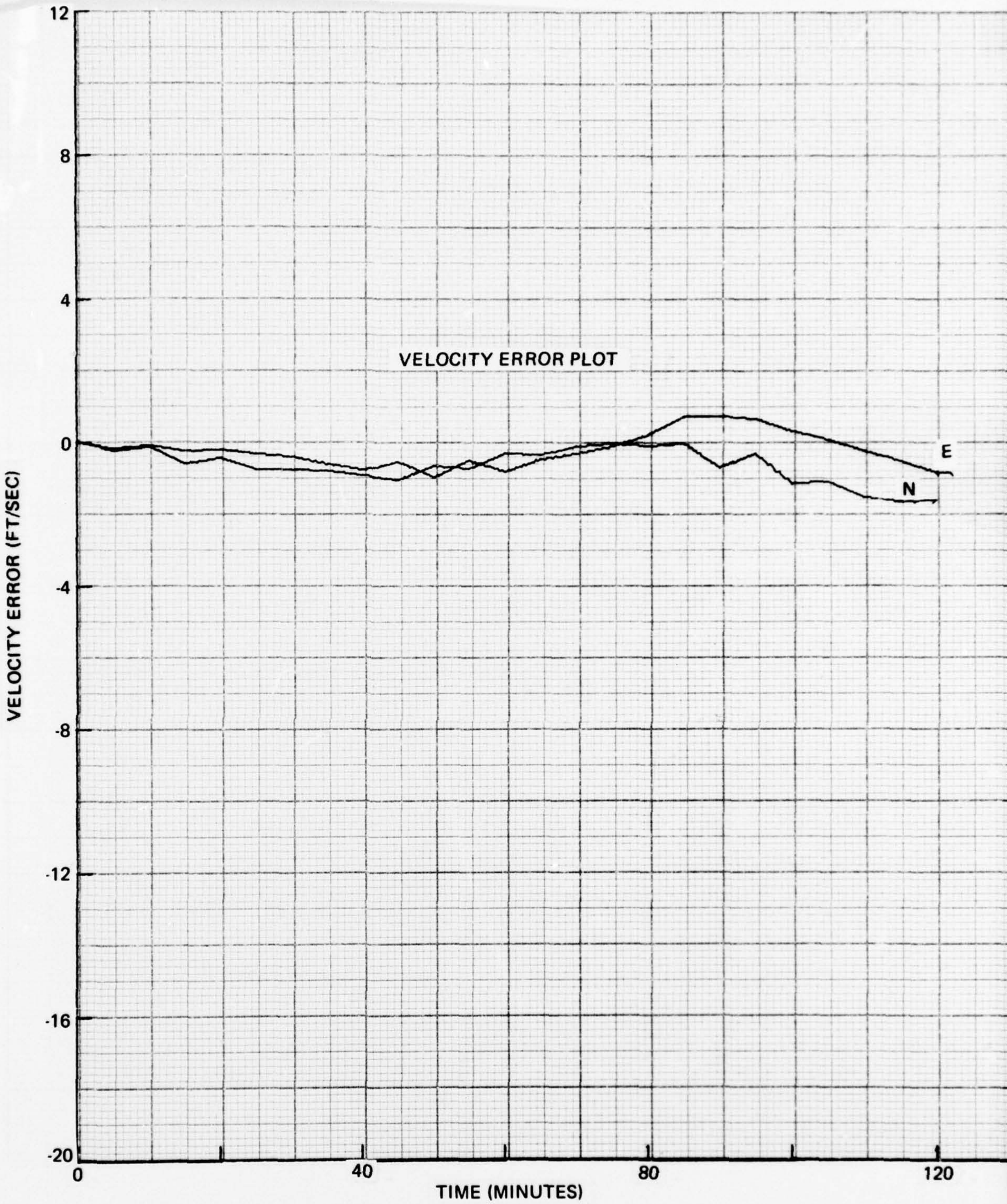


Figure N-29. EPM 2 NAV Run 0214770307, 90 Deg Heading

1


R
120


VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
12
8
4
0
-4
-8
-12
-16
-20
0
40
80
120
TIME (MINUTES)
E
N

2

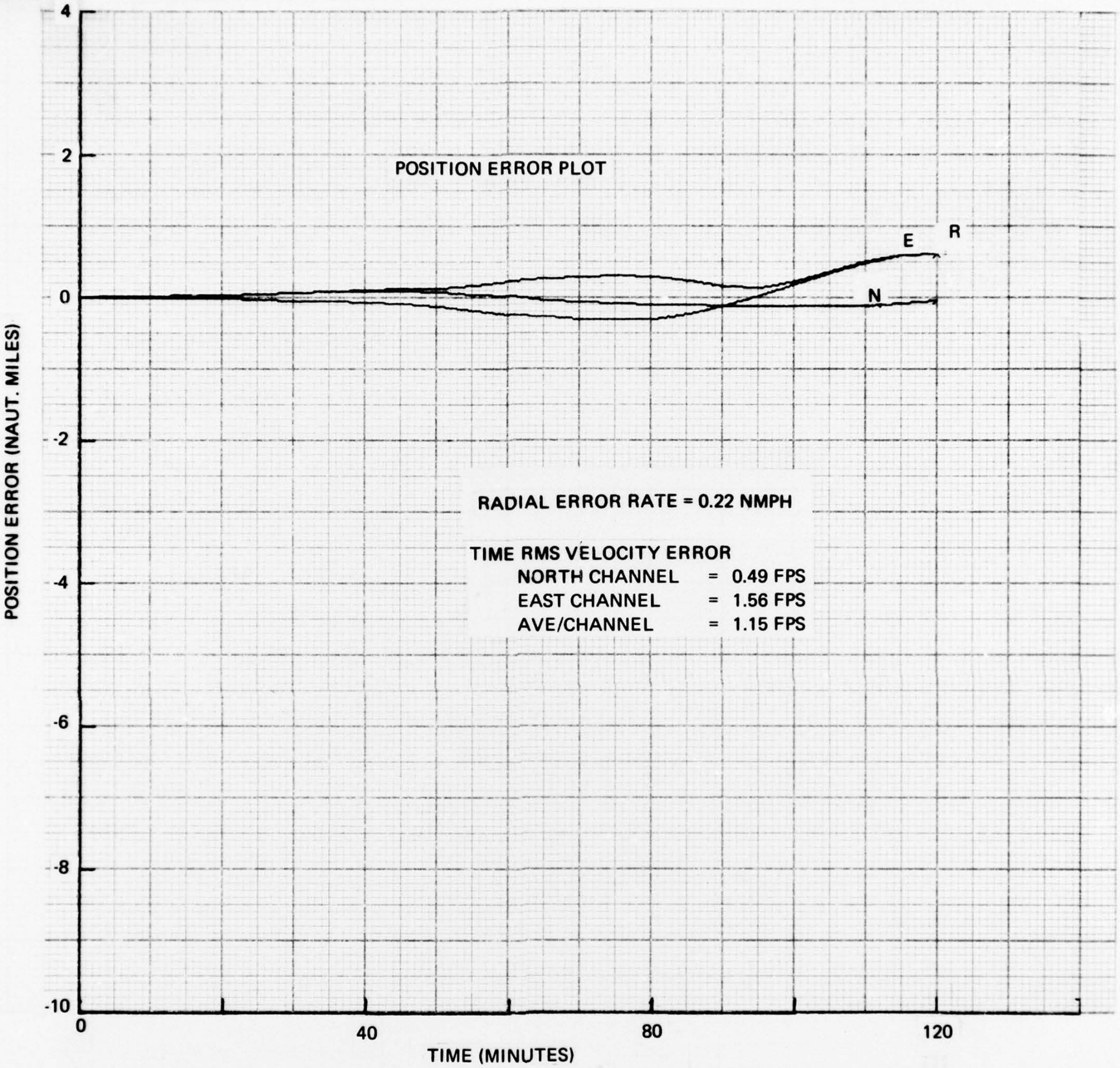
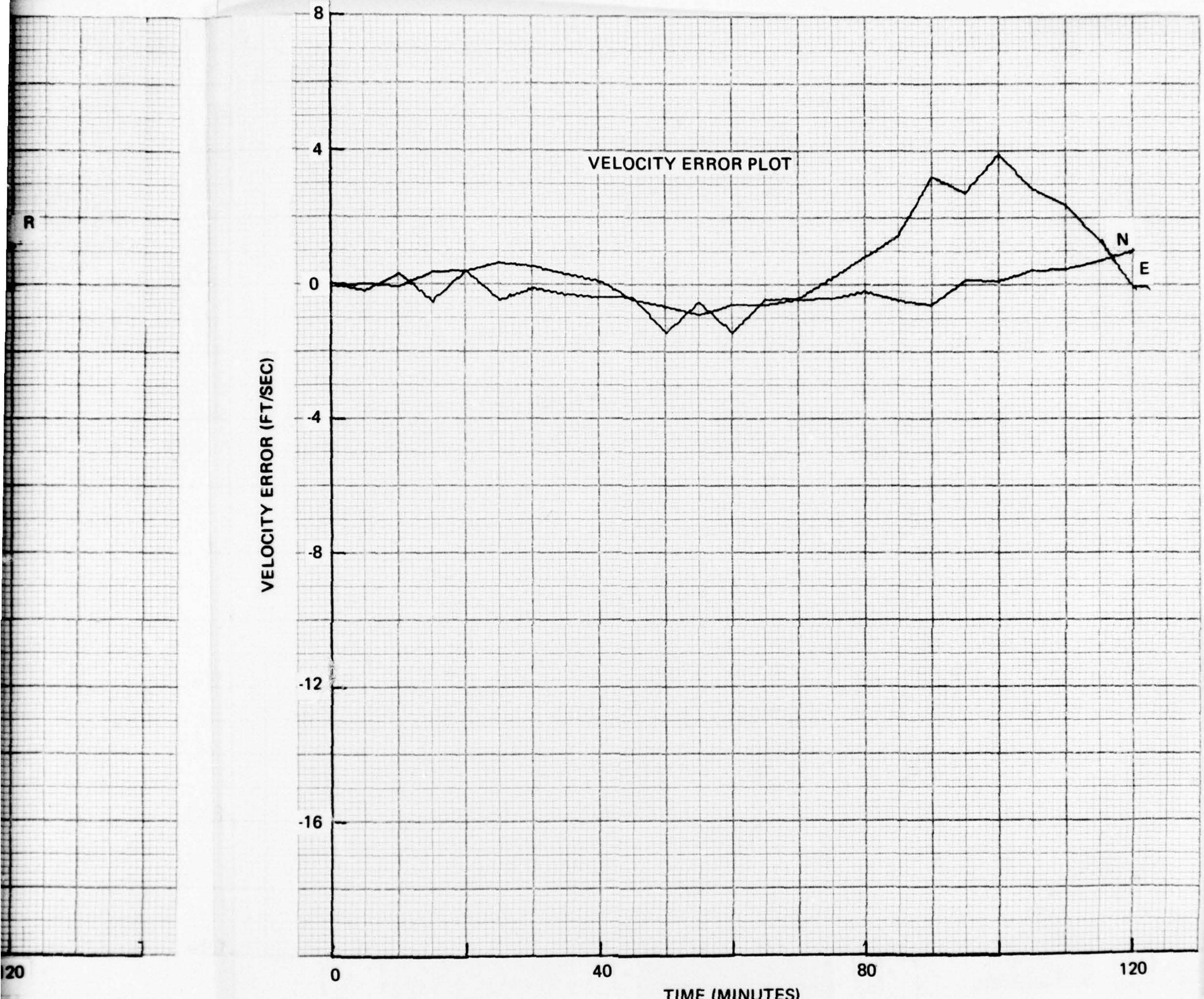


Figure N-30. EPM 2 NAV Run 0214770528, 0 Deg Heading

1


VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
TIME (MINUTES)
8
4
0
-4
-8
-12
-16
0
40
80
120
N
E
R
120

2

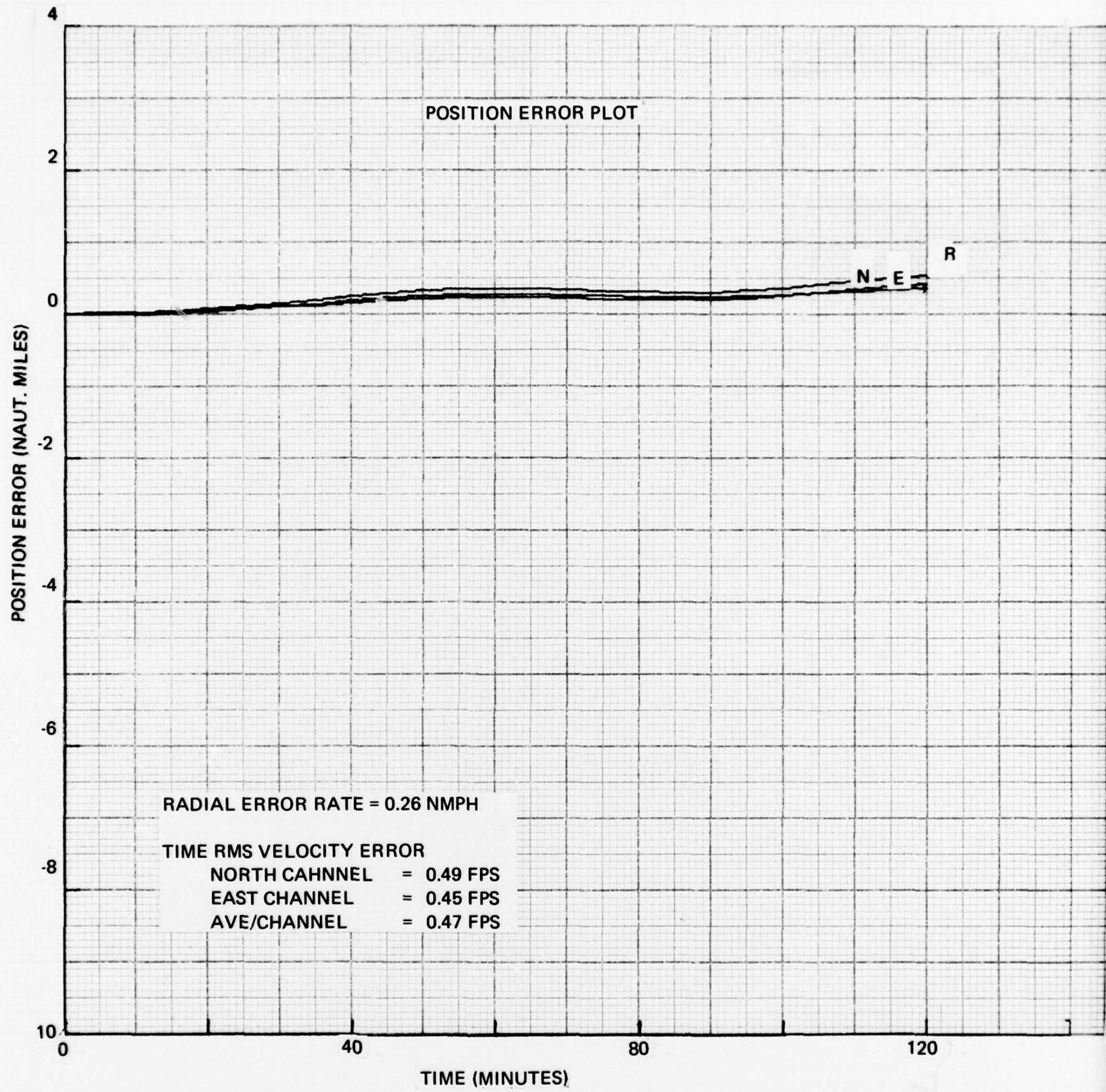
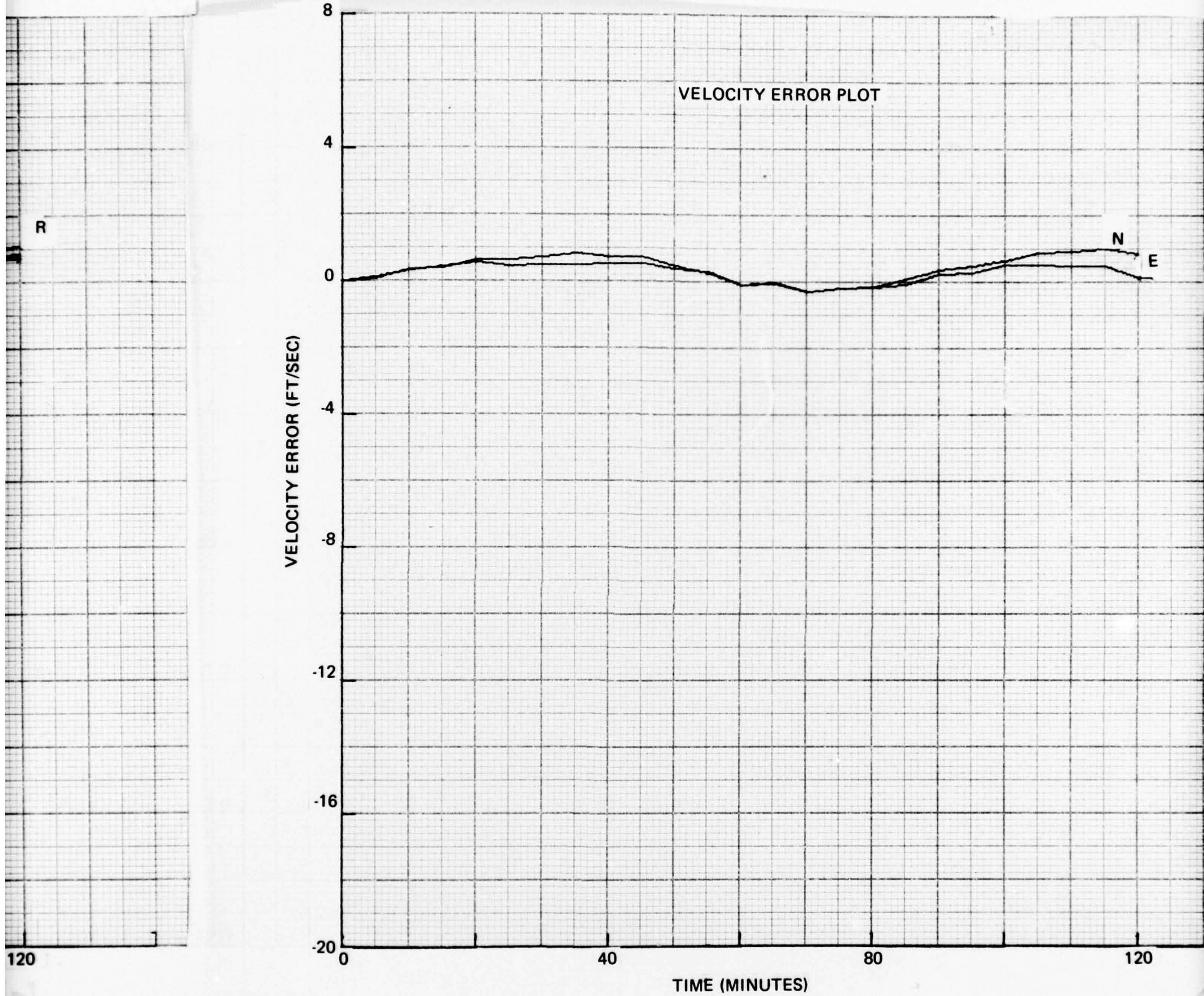


Figure N-31. EPM 2 NAV Run 0214771713, 0 Deg Heading

1



VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
8
4
0
-4
-8
-12
-16
-20
0
40
80
120
TIME (MINUTES)
N
E
R
120

2

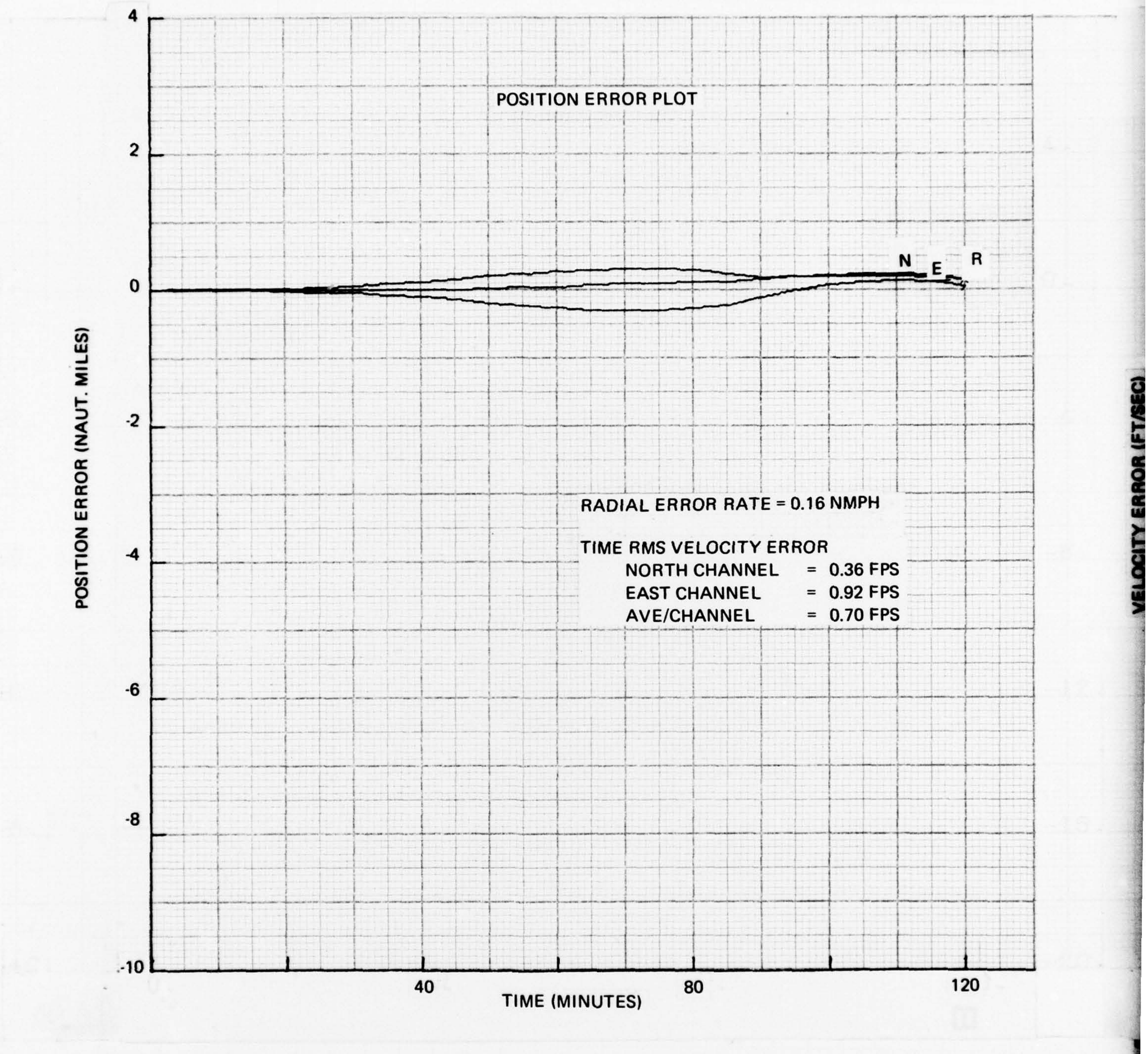
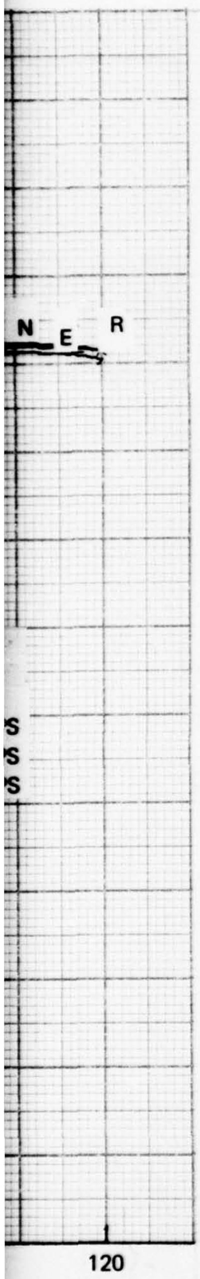
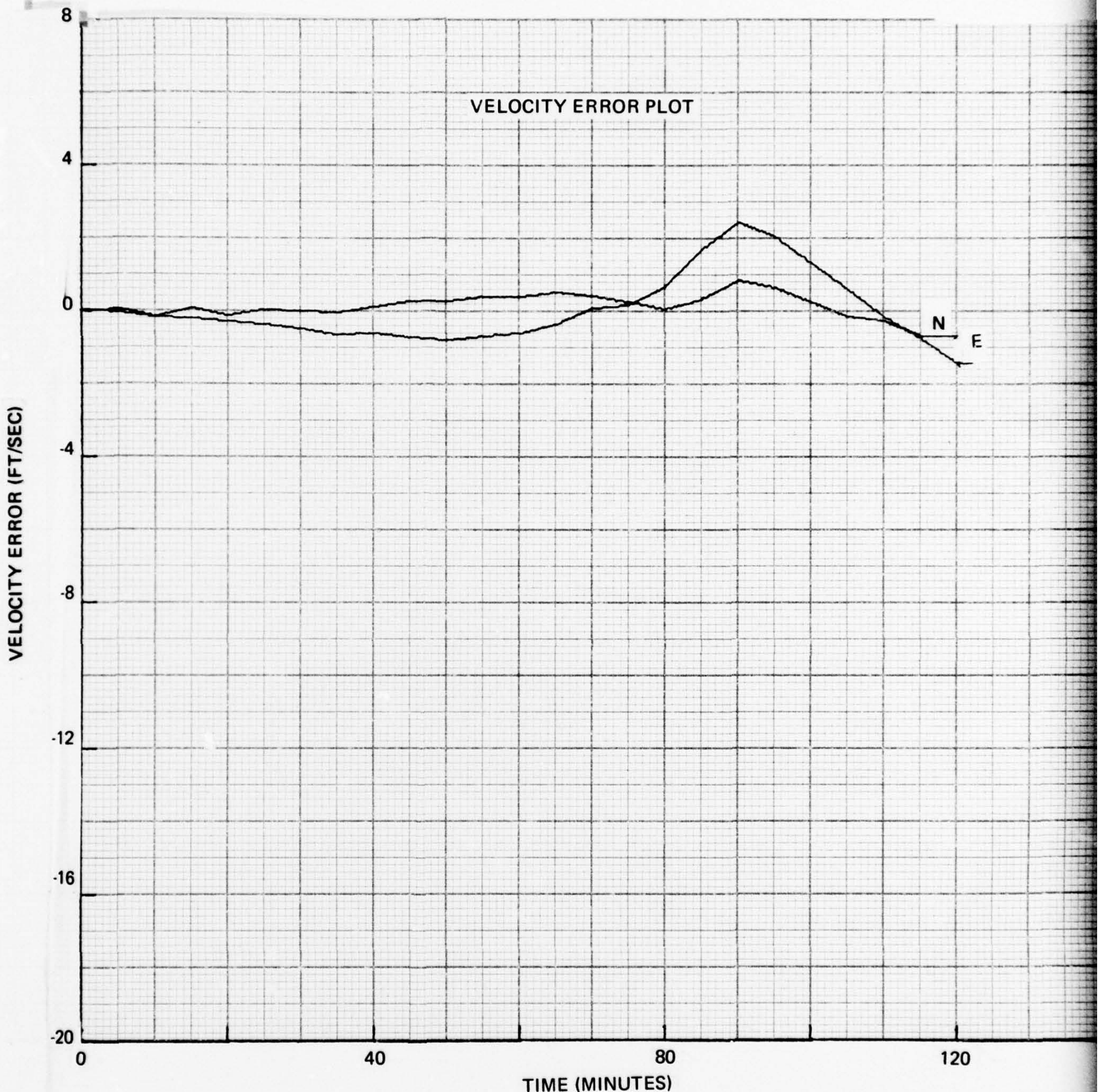


Figure N-32. EPM 2 NAV Run 0214771945, 90 Deg Heading

1


N
E
R
120
S
S
S


VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
8
4
0
-4
-8
-12
-16
-20
0
40
80
120
TIME (MINUTES)
N
E

2

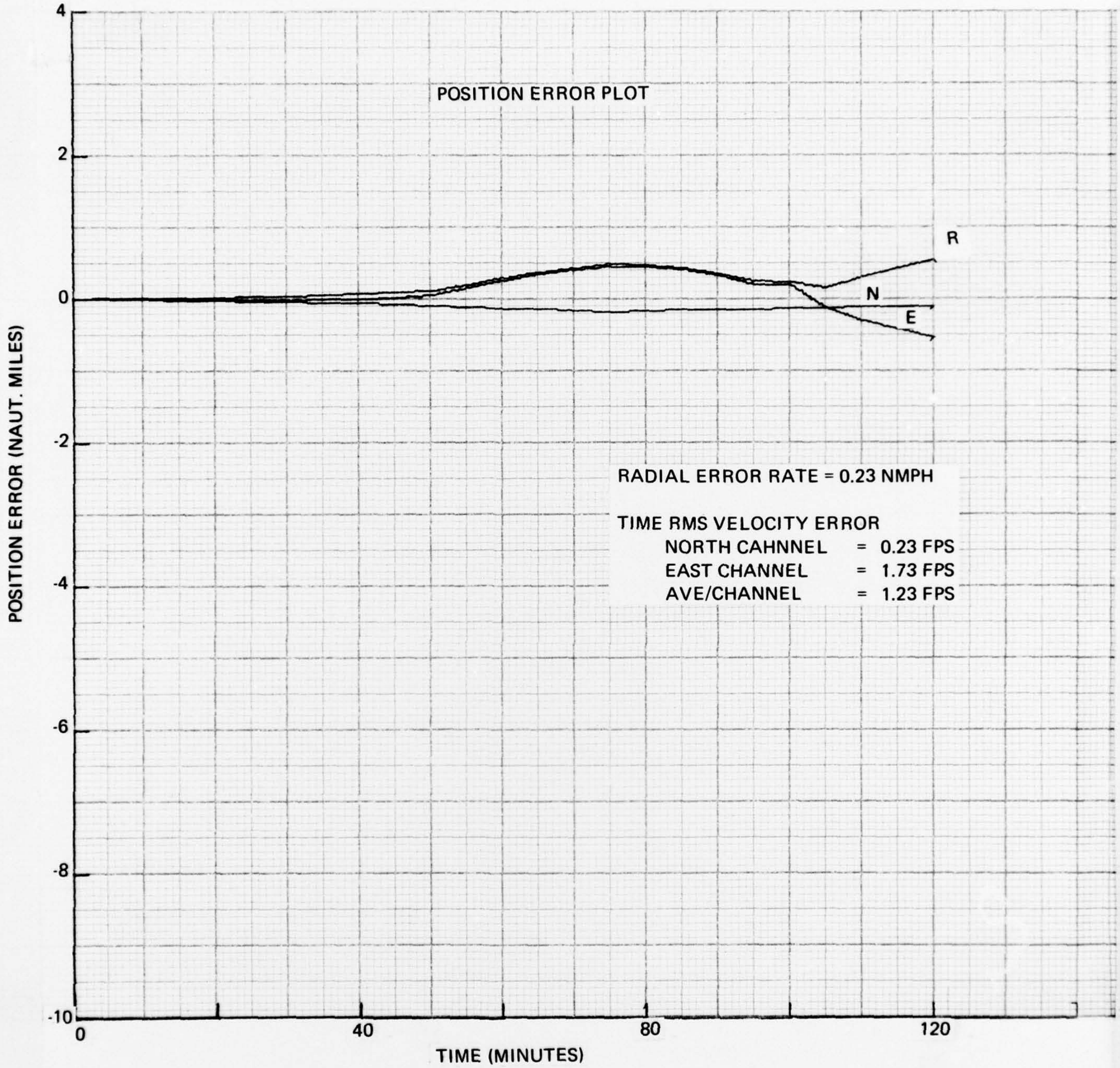
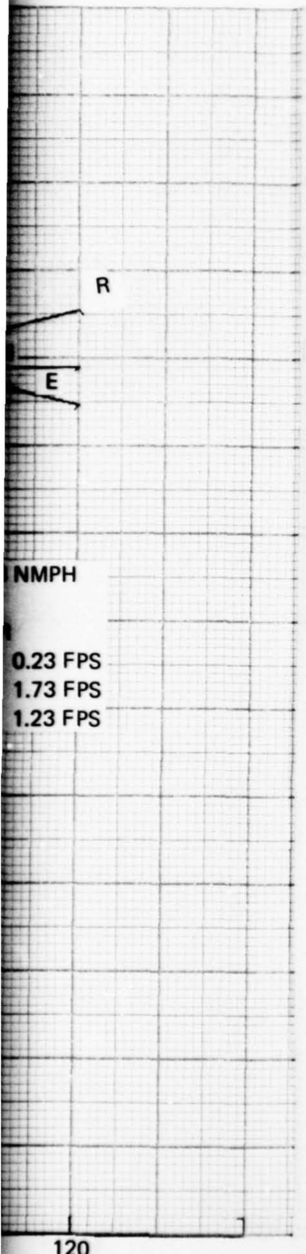
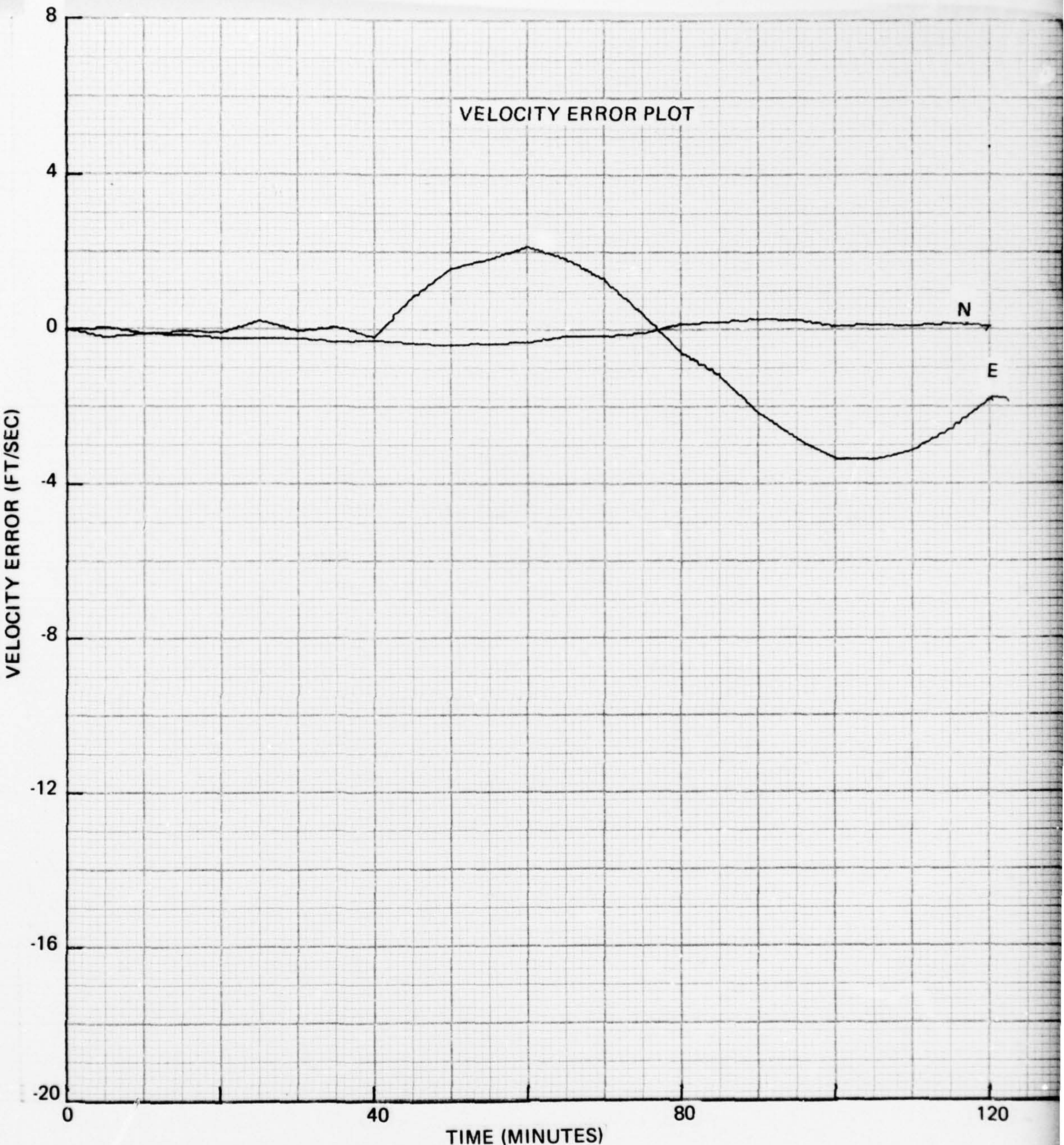


Figure N-33. EPM 2 NAV Run 0214772212, 0 Deg Headin

1



R
E
NMPH
0.23 FPS
1.73 FPS
1.23 FPS
120



VELOCITY ERROR PLOT
VELOCITY ERROR (FT/SEC)
8
4
0
-4
-8
-12
-16
-20
N
E
0
40
80
120
TIME (MINUTES)

2